STATE OF CALIFORNIA

The Resources Agency

Department of Water Resources

BULLETIN No. 171

UPPER EEL RIVER DEVELOPMENT

INVESTIGATION OF ALTERNATIVE CONVEYANCE ROUTES

AUGUST 1967

RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
Director
Department of Water Resources

STATE OF CALIFORNIA
The Resources Agency
Department of Water Resources

BULLETIN No. 171

UPPER EEL RIVER DEVELOPMENT

INVESTIGATION OF ALTERNATIVE CONVEYANCE ROUTES

AUGUST 1967

RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
Director
Department of Water Resources

FOREWORD

The Upper Eel River Development was authorized by the Department of Water Resources in March 1964 as the first additional facility of the State Water Project. Advance planning studies on the development were initiated in July 1964.

The first phase of the Advance Planning Program has been a three-year investigation of the alternative conveyance routes for diversion of surplus water from the Middle Fork Eel River to the Sacramento--San Joaquin Delta. The second phase will be formulation of a definite project.

This report presents the results of the investigation of the two alternative conveyance routes from the Middle Fork Eel River; one easterly via the proposed Glenn Reservoir Complex on Thomes and Stony Creeks in Tehama and Glenn Counties and the other southerly via the proposed English Ridge Reservoir on the Upper Main Eel River through Clear Lake and Cache Creek to the Sacramento River.

On the basis of this investigation, it is concluded that the easterly routing through the Glenn Reservoir Complex is the more favorable of the two alternatives. The Department's investigation of the alternative conveyance routes has been conducted in cooperation with the U. S. Bureau of Reclamation, Corps of Engineers, and Soil Conservation Service. These agencies all concur in the conclusion that the Glenn Reservoir routing is the more favorable. The Glenn Reservoir routing for the Middle Fork Eel River Development is hereby selected for further feasibility-level study.

Tentative indications are that the conservation features on the Middle Fork Eel River and elements of the Glenn Reservoir Complex could provide a firm conservation yield substantially greater than that needed by the present State Water Project. This supplemental water could be used to meet future demands on the Central Valley Project or the State Water Project, or both.

The Middle Fork Eel River Development is important not only from the standpoint of supplying water to meet needs in other areas of the State, but also in providing needed flood control and recreation to the North Coastal area.

The Department will continue its advance planning studies to define the conservation features on the Middle Fork Eel River, the Dos Rios--Grindstone Tunnel, the Glenn Reservoir features, and the associated conveyance works. These studies, conducted cooperatively with the federal agencies, will provide a logical basis for proceeding with design, acquisition of rights-of-way, and construction of the project.

Director
Department of Water Resources
The Resources Agency
State of California

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

RONALD REAGAN, Governor
WILLIAM R. GIANELLI, Director, Department of Water Resources
JOHN R. TEERINK, Deputy Director

NORTHERN DISTRICT

Gordon W. Dukleth . . . . District Engineer
Stuart T. Pyle . . . . Chief, Planning Section

This report was prepared under the direction of

George R. Baumli . . . . Chief, Advance Planning Unit

by

John M. Youngerman . . . . Associate Engineer
Michael P. Price . . . . Associate Engineer
Kenneth R. Henneman . . . . Engineering Associate
Thomas L. Hanson . . . . Assistant Engineer

assisted by

Gregory M. Voge . . . . Assistant Engineer
Warren H. Parker . . . . Engineering Technician II
Willis T. Cox . . . . Engineering Aid I
Edward A. Pearson . . . . Research Writer

Special services were provided by

Design and Cost Estimating

Linton A. Brown	Senior Engineer
Robert A. Steel	Associate Engineer
Donald S. Slebodnick	Engineering Associate
David J. Cahoon	Assistant Engineer
John G. Linkswiler	Assistant Engineer
Archie H. Matthews	Assistant Engineer
James H. Pankratz	Assistant Engineer
Robert F. Morehouse	Engineering Aid I

Rights of Way

Robert L. Reaves	Associate Land Agent
Richard D. Linstrom	Assistant Land Agent

Fish and Wildlife

John M. Hayes	Fishery Biologist IV
Lee F. Goodson, Jr.	Fishery Biologist III
Ralph N. Hinton	Fishery Biologist III
Carl E. Lindquist	Wildlife Manager III
Victor Simpson	Game Manager II

Economics

Walter L. Quincy	Senior Economist

Geology

Philip J. Lorens	Senior Eng'g Geologist
Ralph G. Scott	Associate Eng'g Geologist
Robert J. Brand	Assistant Eng'g Geologist
Michael J. Dwyer	Assistant Eng'g Geologist
Michael E. Huffman	Assistant Eng'g Geologist
James V. Vantine	Assistant Eng'g Geologist
Tom M. Wootton	Assistant Eng'g Geologist
Russell C. Bingley	Junior Eng'g Geologist
Robert D. Perry	Junior Eng'g Geologist
Darrel J. Huckabay	Engineering Technician I
Robert G. Stillwell	Engineering Technician I
Austin E. Gilligan	Engineering Associate

Water Quality

Robert F. Clawson	Senior Engineer
Richard L. Rosenberger	Engineering Associate
Jerry E. Dillard	Engineering Aid II

Recreation

George E. Reiner	Recreation Planner III
James M. Doyle	Recreation Planner II

TABLE OF CONTENTS

FIGURES

TABLES

OFFICE REPORTS

The technical studies made in the investigation of the alternative conveyance routes have been compiled in the form of office reports. These office reports listed below, although not for general distribution, are available for inspection at the Department's offices.

Alternative Plans for Development

Hydrology

Designs and Cost Estimates
- Volume 1 - Glenn Reservoir Features
- Volume 2 - Middle Fork Eel River Dams and Reservoirs
- Volume 3 - Tunnels and Pumping Plants
- Volume 4 - English Ridge Dam and Reservoir
- Volume 5 - Cache Creek Features
- Volume 6 - Putah Creek Features

Engineering Geology
- Etsel Damsite
- Mill Creek Damsite
- Round Valley Drainage Tunnel
- Elk Creek Tunnel
- Dos Rios--Grindstone Tunnel
- Construction Materials - Middle Fork Eel River

Water Quality

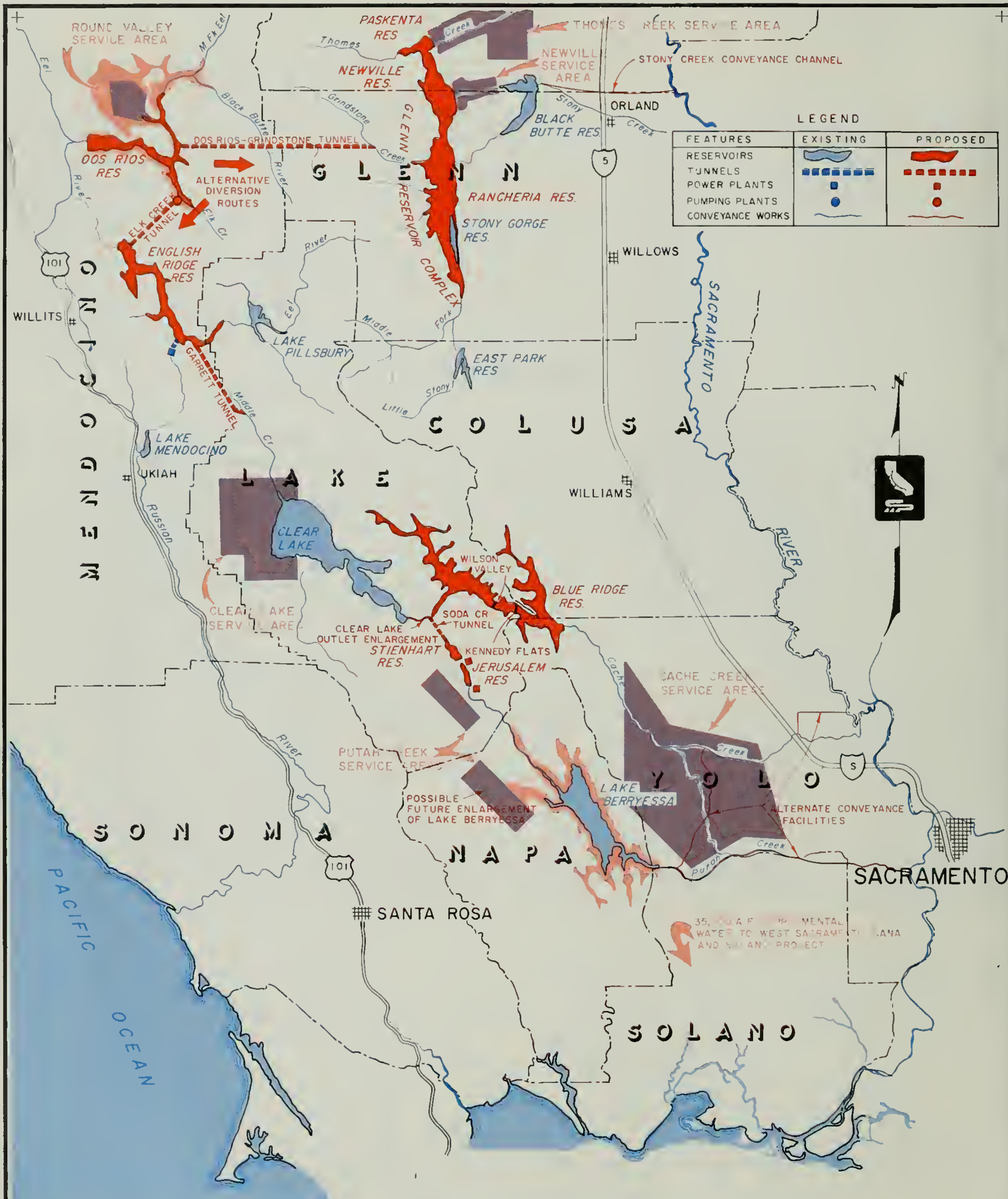
Fish and Wildlife

Recreation
- Recreation Use and Cost Estimates for Alternative Conveyance Routes
- Recreation Reconnaissance - English Ridge Reservoir
- Recreation Reconniassance - Paskenta-Newville Project

ABSTRACT

The Glenn Route is the best route for conveyance of Middle Fork Eel River water to the Sacramento--San Joaquin Delta for use in the State Water Project by the year 1990. Water will flow from the Middle Fork Eel River east through Glenn and Tehama Counties to the Sacramento River and then to the Delta; the alternative route investigated would have been through Clear Lake and down the Sacramento River either through Cache Creek or Putah Creek. / Routing of Middle Fork Eel River water through Clear Lake on the planned operational schedule would not result in any substantial change in present water quality conditions in the lake. The water temperature in the lake would be lowered very slightly during the summer but neither the turbidity nor the algae problems would be alleviated. The present mineral quality of lake water is generally good; only minor improvement could be expected. / There would be an appreciable cost savings in routing water from reservoirs on the lower Eel River to the Sacramento Valley via the Glenn reservoirs rather than via Clear Lake. / The most likely plan of development for the Glenn Route appears to be a combination of Dos Rios Reservoir on the Middle Fork Eel River, the Dos Rios--Grindstone Tunnel, and features of the Glenn Reservoir Complex. A dam could be constructed at the Dos Rios site, which is one of the best in the North Coastal area, to impound a reservoir up to a normal water surface elevation of approximately 1610 feet, storing 8,000,000 acre-feet of water. / The Paskenta-Newville Project on Thomes and North Fork Stony Creeks is one of the more favorable remaining water projects in the Sacramento Valley. It could be developed independently or it could be integrated into the Upper Eel River or Trinity River Developments as part of the Glenn Reservoir Complex. / The English Ridge Project on the upper main Eel River is the logical source of water for service of ultimate needs in the Clear Lake--upper Putah Creek areas. / This report concludes the first, or route selection, phase of the advance planning studies on the Upper Eel River Development. During the second phase, detailed studies will be made to formulate the actual project and its component features.

FIGURE 1



POSSIBLE FEATURES
OF THE
UPPER EEL RIVER DEVELOPMENT

SCALE OF MILES
0 4 8 16 24

CHAPTER 1. SUMMARY

The Upper Eel River Development has been selected as the initial North Coastal facility of the State Water Project. In July 1964, an Advance Planning Program was initiated to define the features of this development. This report presents the results of the first phase of this program, which was directed toward a determination of the best diversion route for delivering project water from the Middle Fork Eel River to the Sacramento--San Joaquin Delta.

Two alternative conveyance routes were studied, one easterly through Glenn and Tehama Counties, and the other southerly through Clear Lake in Lake County. The features of these routes are shown on Figure 1 on the opposite page.

The alternative Glenn and Clear Lake conveyance routes were compared for a wide range of sizes using traditional benefit-cost standards for economic comparison. All aspects, such as flood control, recreation, local water needs, water quality, fish and wildlife, hydroelectric power and statewide water needs, normally considered in a water resources planning investigation were evaluated. Consideration was also given to integration of future lower Eel River developments and to conformance with the California Water Plan.

In the course of the route selection studies, considerable engineering data was developed on individual project alternatives on the Middle Fork Eel River and on each of the routes. Analysis of this data has better defined the role of the various project features in plans for future water development.

The following section presents the conclusions arrived at as a result of the investigation of the alternative conveyance routes.

Conclusions

It is concluded that:

1. The Glenn Route is by engineering and economic standards of comparison the superior route for diversion of Middle Fork Eel River water to the Sacramento--San Joaquin Delta. This conveyance route is in conformance with the California Water Plan.

2. The English Ridge Project on the Upper Main Eel River is a logical source of water for service of ultimate needs in the Clear Lake-Upper Putah Creek areas and could be constructed independently of the Middle Fork Eel River Development.

3. The most likely plan of development for the Glenn Route is a combination of Dos Rios Reservoir on the Middle Fork Eel River, the Dos Rios--Grindstone Tunnel, and features of the Glenn Reservoir Complex.

4. Further feasibility level planning studies of the Middle Fork Eel River Development should be confined to the Glenn Route. Detailed studies are required to determine the optimum size of Dos Rios Reservoir, Dos Rios--Grindstone Tunnel, and the features of the Glenn Complex.

5. There would be an appreciable cost savings in routing water from reservoirs on the lower Eel River to the Sacramento Valley via the Glenn reservoirs rather than via Clear Lake. Additional studies are required to determine timing, scale, and ultimate diversion route for the Lower Eel River Development.

6. The Franciscan damsite (northeast of Covelo) is not suitable for a dam of the sizes considered because of unfavorable foundation conditions. The Etsel and Spencer damsites on the Middle Fork Eel River should be eliminated from further consideration because of high costs and uncertainties regarding the competence of foundation materials.

7. Routing of Middle Fork Eel River water through Clear Lake on the planned operational schedule would not result in any substantial change in present water quality conditions in the lake. The water temperature in the lake would be lowered very slightly during the summer but neither the turbidity nor the algae problems would be alleviated.

The present mineral quality of lake water is generally good; only minor improvement could be expected.

Historical Background

California's State Water Project, which constitutes the initial facilities of the State Water Resources Development System, is being constructed by California to help meet the expansion of the state's water needs until approximately 1990.

The State Water Project has a contractual commitment to deliver 4,230,000 acre-feet of water annually to the water users. This entire commitment is expected to be met, essentially, by 1990. However, continued increases in upstream development will reduce the supply of water available for export from the Sacramento--San Joaquin Delta. To insure that delivery commitments will be met, additional water conservation facilities must be constructed in time to supplement the supply of water in the Delta.

In addition to meeting water delivery requirements, the water in the Delta must be maintained at a quality suitable for fish, wildlife, and recreational use of the waterways. This is an important consideration in planning for future needs.

The undeveloped North Coastal rivers are the remaining available major source of water in California for the expanding needs of the state's population and industry. A seven-year reconnaissance study of the North Coastal area was completed in 1964 and reported upon in Department Bulletin No. 136, "North Coastal Area Investigation". The objective of this study was to formulate plans for the orderly, staged development of the water resources of that region and to select the initial project.

A primary conclusion of Bulletin No. 136 was that "A multiple-purpose water conservation project drawing surplus water from the Upper Eel River is the most favorable initial North Coastal development for providing augmentative water supplies to the State Water Project...."

In accordance with this conclusion, the Director of the Department of Water Resources issued a project order in 1964 authorizing the Upper Eel River Development as the first additional facility for the State Water Project. This project order specified that the project would consist of water conservation features on the Middle Fork Eel River but did not specify the route by which the water would be transferred to the Sacramento Valley and thence to the Sacramento--San Joaquin Delta. An Advance Planning Program was initiated to provide the necessary basic data and engineering and economic analyses for selection of the conveyance route and to define the exact project which should be built.

There are basically two alternative routes by which Middle Fork Eel River water may be transported to the Sacramento Valley. One is known as the Glenn Route, a gravity diversion eastward by tunnel through the Coast Range mountains to large reservoirs in Glenn and Tehama Counties. The other is by pumped diversion to the proposed English Ridge Reservoir on the upper main Eel River where it would flow by gravity through a tunnel to Clear Lake and then to a large storage reservoir on either Cache Creek or Putah Creek.

In order to provide a basis for the selection and sizing of the features of the Upper Eel River Development, it was first necessary to determine the proper route for conveyance of the water. To do this, the Advance Planning Program was divided into two distinct phases. Phase I, the comparison of the alternative conveyance routes, is reported upon in this bulletin. Phase II, definite project formulation initiated in July 1967, will culminate with publication of a bulletin giving complete details of the selected project and its component features.

The primary purpose of the studies reported on in this bulletin has been to amass sufficient data to make possible a clear, reasoned choice of the best route for conveyance of the water from the Middle Fork Eel River. Although the investigation has given some indication of the most economical and probable development, more detailed studies will be required in Phase II to formulate the actual project which will be constructed.

The Alternative Conveyance Routes

This section explains the major features of each of the two alternative routes studied.

The Glenn Route

Figure 2 shows a plan and profile of the Glenn Route. The water conservation facility shown on the Middle Fork Eel River is the proposed Dos Rios Reservoir. A dam could be constructed at the Dos Rios site, which is one of the best in the North Coastal area, to impound a reservoir up to a normal water surface elevation of approximately 1610 feet, storing 8,000,000 acre-feet of water. This size of reservoir would include storage in Round Valley. The largest size of Dos Rios Reservoir that could be constructed without inundating Round Valley would store 536,000 acre-feet of water with a water surface elevation of 1320 feet. Further studies will determine the optimum scale of development of the Middle Fork Eel River features.

Diversion from Dos Rios Reservoir to the Sacramento Valley would be by means of a gravity-flow tunnel, about 14 feet in diameter and 21.2 miles long; no pumping would be necessary. If Round Valley were inundated, the minimum water surface elevation in Dos Rios Reservoir would be about 1400 feet, ensuring that from 50 to 100 feet of water would always cover the valley floor. This would further enhance the outstanding recreation potential on this reservoir, which would have a normal water surface area of 40,000 acres, approximately the same size as Clear Lake. Diversion from a lower level Dos Rios Reservoir with a water surface elevation of 1320 feet and a surface area of 4,400 acres, would also be via a gravity-flow tunnel about 14 feet in diameter, but in this case about 23.4 miles long. The minimum water surface elevation for this reservoir would be 1200 feet.

The proposed Rancheria Reservoir, the southernmost feature of the Glenn Reservoir Complex, would provide storage in the Sacramento Valley for year-by-year reregulation of flows and for long-term carryover storage. Rancheria Reservoir at a normal water surface elevation of 1,000 feet would have a capacity of 5,060,000 acre-feet, and a water surface area of 35,000 acres. Additional studies are required to size the reservoir, which could be constructed to impound up to about 10,000,000 acre-feet.

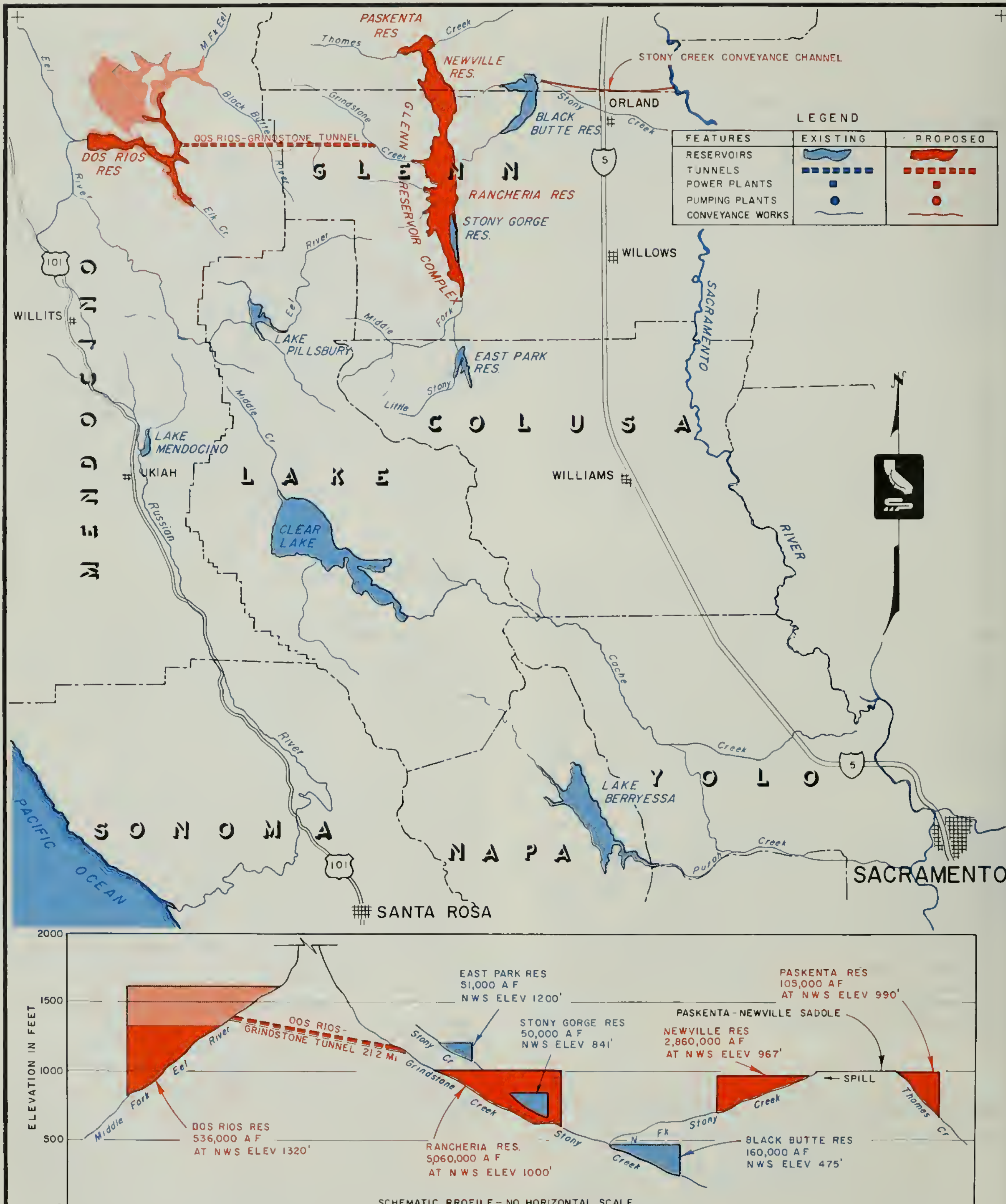
Although the two remaining units of the Glenn Complex, Paskenta Reservoir and Newville Reservoir, could be developed independently as the Paskenta-Newville Project, as discussed in Chapter 7, further studies will be required to determine if it is more advantageous from the standpoint of economics and long-range water development plans to integrate them into the Upper Eel River Development.

Paskenta Reservoir on Thomes Creek would serve as a diversion structure to spill flood flows and other surplus flows into Newville Reservoir. Paskenta Reservoir would be constructed to a normal water surface elevation sufficient to allow diversion through a natural channel, elevation 990 feet, into Newville Reservoir. Newville Reservoir on North Fork Stony Creek would be formed by a dam across Rocky Ridge through which the creek flows. It could be constructed to a normal water surface elevation of about 970 feet, storing 2,900,000 acre-feet of water. Surplus flows from the Middle Fork Eel River could be transferred from Rancheria Reservoir to Newville Reservoir through the Chrome saddle between the two reservoirs. The project water would be conveyed from the Glenn Complex to the Sacramento River via Black Butte Reservoir and Stony Creek. The continuing planning studies will determine the best plan of development of the Glenn Complex features, including the possibility of hydroelectric power generation.

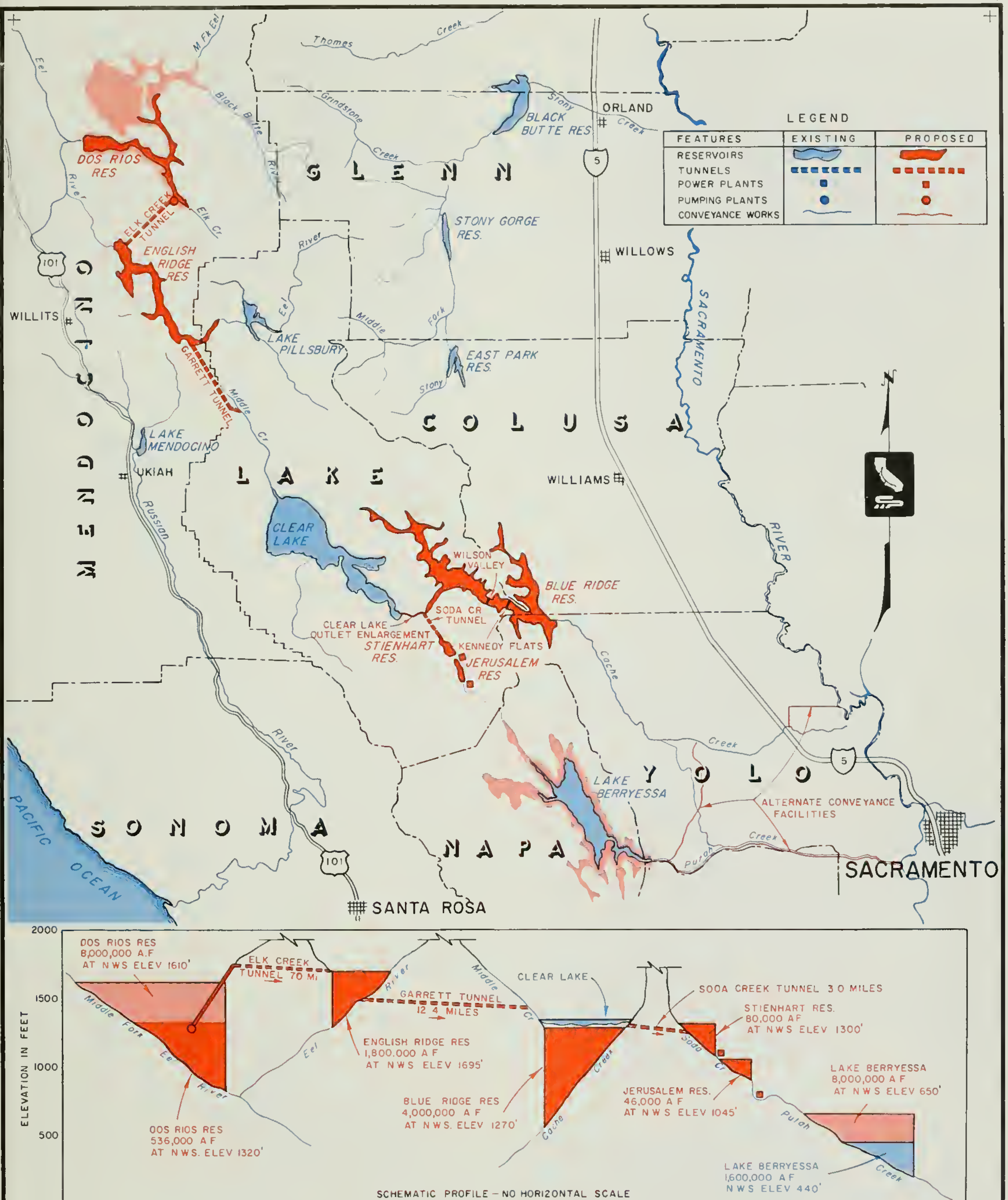
<u>The Clear Lake Route</u>

Figure 3 shows a plan and profile of possible features of the Clear Lake Route. The water conservation facility shown on the Middle Fork Eel River is again Dos Rios Reservoir to a normal water surface elevation of 1610 feet. The diverted water would be pumped against a maximum head of 350 feet, including friction losses, by the Elk Creek Pumping Plant, into Elk Creek Tunnel, 14 feet in diameter, 7.0 miles long, to English Ridge Reservoir. This proposed reservoir is being studied by the U. S. Bureau of Reclamation to provide water for local needs in the Cache and Putah Creek basins and for other needs in the Sacramento--San Joaquin Delta. The reservoir would have a normal water surface elevation of 1698 feet, impounding 1,800,000 acre-feet of water.

The project water from the Middle Fork Eel River, along with that from the English Ridge Project, would flow southeasterly through English Ridge Reservoir to the intake of Garrett Tunnel at elevation 1495 feet. This tunnel, 14 feet in diameter and 12.4 miles long, would divert the water to Middle Creek, a tributary of Clear Lake. From Clear Lake, the water would pass through an enlarged outlet into a large storage reservoir on Cache Creek. Three alternative Cache Creek sites have been considered: Wilson Valley Reservoir, to a maximum normal water surface elevation of



POSSIBLE FEATURES OF THE
GLENN ROUTE ALTERNATIVE
UPPER EEL RIVER DEVELOPMENT



POSSIBLE FEATURES OF THE
CLEAR LAKE ALTERNATIVE
UPPER EEL RIVER DEVELOPMENT

SCALE OF MILES
0 4 8 16 24

1228 feet, storing 1,000,000 acre-feet of water; Kennedy Flats Reservoir, to a maximum normal water surface elevation of 1310 feet, storing 2.25 million acre-feet of water; and Blue Ridge Reservoir, to a maximum normal water surface elevation of 1270 feet, storing 4,000,000 acre-feet of water. The project water from the Cache Creek Reservoir would reach the Sacramento River via Cache Creek and a special conveyance channel, with a large inverted siphon under the Knights Landing Ridge Cut.

An alternative conveyance and storage route from Clear Lake which was considered in Bulletin No. 136 would be to divert the water at the outlet of Clear Lake through the Soda Creek Tunnel, 17 feet in diameter and 3 miles long, to Soda Creek, a tributary of Putah Creek, then to an enlarged Lake Berryessa. By constructing an earthfill dam one mile downstream from the existing Monticello Dam, a large storage reservoir for imported flows could be obtained. The extensive dislocation of the lake shore development, high cost, fisheries detriments, and other factors make this project alternative undesirable however, and attention was focussed on Cache Creek as the more desirable Clear Lake conveyance route.

CHAPTER 2. THE ALTERNATIVE CONVEYANCE ROUTES

In order to compare the alternative routes, all possible engineering and economic data was amassed. The following chapters present in summary form the pertinent data which was gathered. The detailed data is included in office reports. The data from the various sources was transformed where possible into monetary terms, and an economic analysis was performed relating the two routes on comparable terms of costs and benefits.

Basis for Comparison of the Routes

The total project water yield during the historically critical 7-year dry period was chosen to provide a uniform standard against which to measure the economic accomplishments of the two routes. This yield is the total of all water developed by the project, including that used locally and that exported to the Sacramento--San Joaquin Delta. The water used locally would meet the projected buildup of demands in the North Coastal area and that exported to the Delta would be used to meet the projected buildup of demands for water now serviceable by the State Water Project. The export water could also help meet the projected future statewide demands serviceable by an expanded State Water Project and the Central Valley Project. In the case of comparisons dealing strictly with State Water Project costs, the yield actually exported to the Delta was used as the basis for comparison. Thus, either the total project yield or the Delta export yield is used as the horizontal scale on all of the figures in this chapter.

A total of 96 individual alternative projects were studied. Each of the possible features on the Middle Fork Eel River, such as Dos Rios Reservoir, was combined in turn with each of the possible features on the Clear Lake Route, such as Wilson Valley Reservoir, and on the Glenn Route, such as Rancheria Reservoir. The 96 studies covered a range of project yield from 400,000 acre-feet per year to 2,000,000 acre-feet per year. Table 6 in Chapter 4 shows each of the combinations studied.

For each of the individual alternatives studied a determination was made of the total yield, the total capital cost including operation, maintenance and replacement costs, and the total benefits attributable to the project. A uniform 4 percent interest rate and 100-year period of analysis were used to reduce the project's operating costs and benefits, which occur on an annual basis far into the future, to their present worth for economic analysis. All costs include allowances for engineering expenses and possible contingencies and for interest on the money spent for engineering and construction.

Utilizing the water yields, derived from the operations studies, computations were made of costs and benefits, benefits-to-cost ratios, net benefits, unit costs and allocated costs. The values thus obtained were then plotted and curves were drawn showing minimum or maximum values for each route.

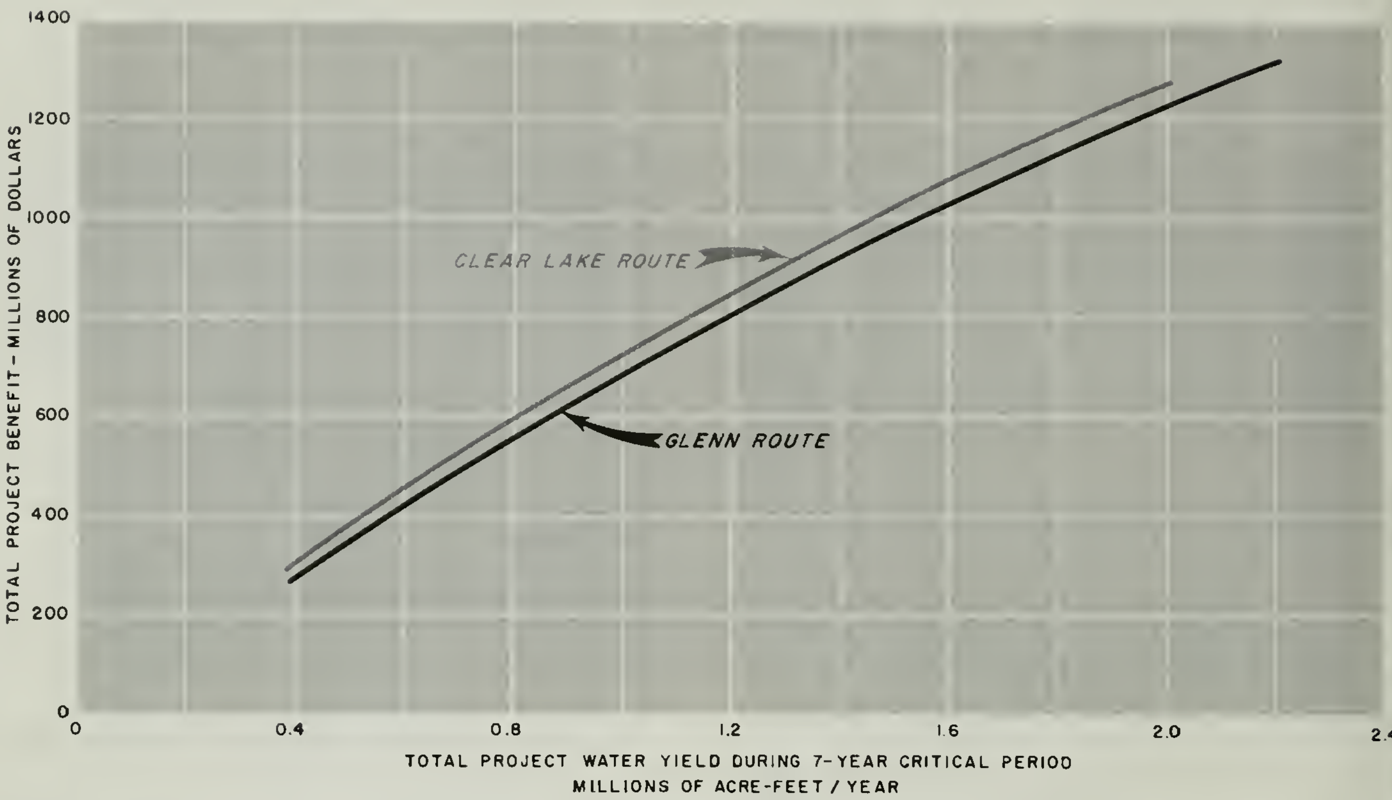
Economic Comparison of the Routes

The actual economic comparisons of the two routes are shown in Figures 4 through 10. Figures 4 through 7 show general economic comparisons of the two routes. Figures 8 through 10 compare the two routes on bases which are of particular interest to State Water Project contractors.

In order to derive the values plotted in Figures 8 through 10, the project costs were allocated, or divided up according to a standard procedure, among the project purposes of flood control, recreation, and water supply. The standard procedure used was the separable costs--remaining benefits method. Briefly, by this method a determination is made of certain costs which are directly attributable to the inclusion of a particular project purpose, such as recreation. When all of these costs are subtracted from the total cost, the remaining costs are apportioned out to each purpose according to an equitable method, utilizing the justifiable expenditure for each project purpose.

Comparison of Total Benefits

The total benefits which would accrue to either route from flood control, recreation, and water supply are compared in Figure 4. A detailed breakdown of the benefits for each project purpose is given in Chapter 4, in the section entitled "Benefits".



COMPARISON OF TOTAL PROJECT BENEFITS
FIGURE 4

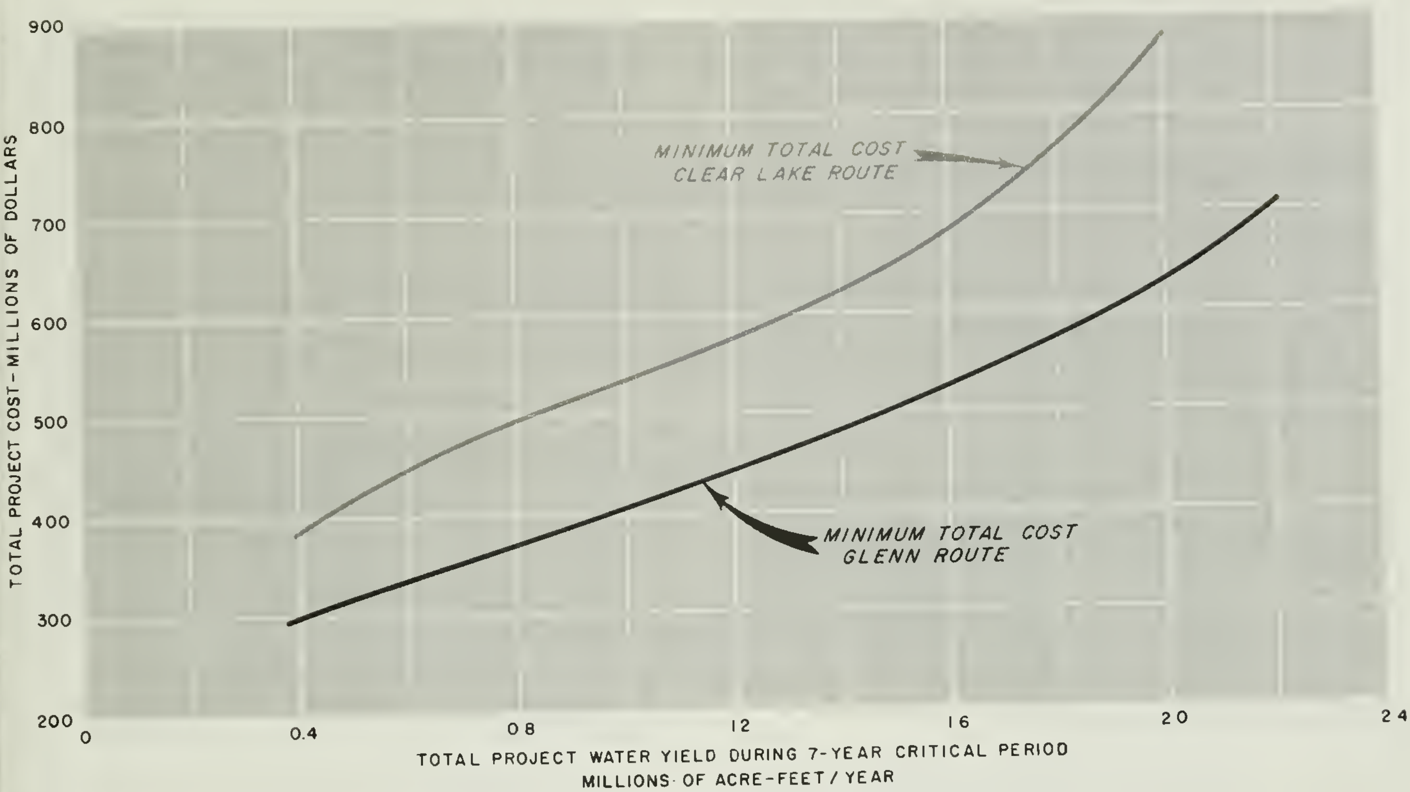
Practically speaking, there is no difference in the total benefits of either route. The Clear Lake Route has marginally greater benefits throughout due primarily to large anticipated recreation developments at English Ridge Reservoir and at the Cache Creek Reservoir, and to provision of flood control for Clear Lake. This latter purpose could be accomplished at nominal cost however, without construction of the Upper Eel River Development.

TABLE 1

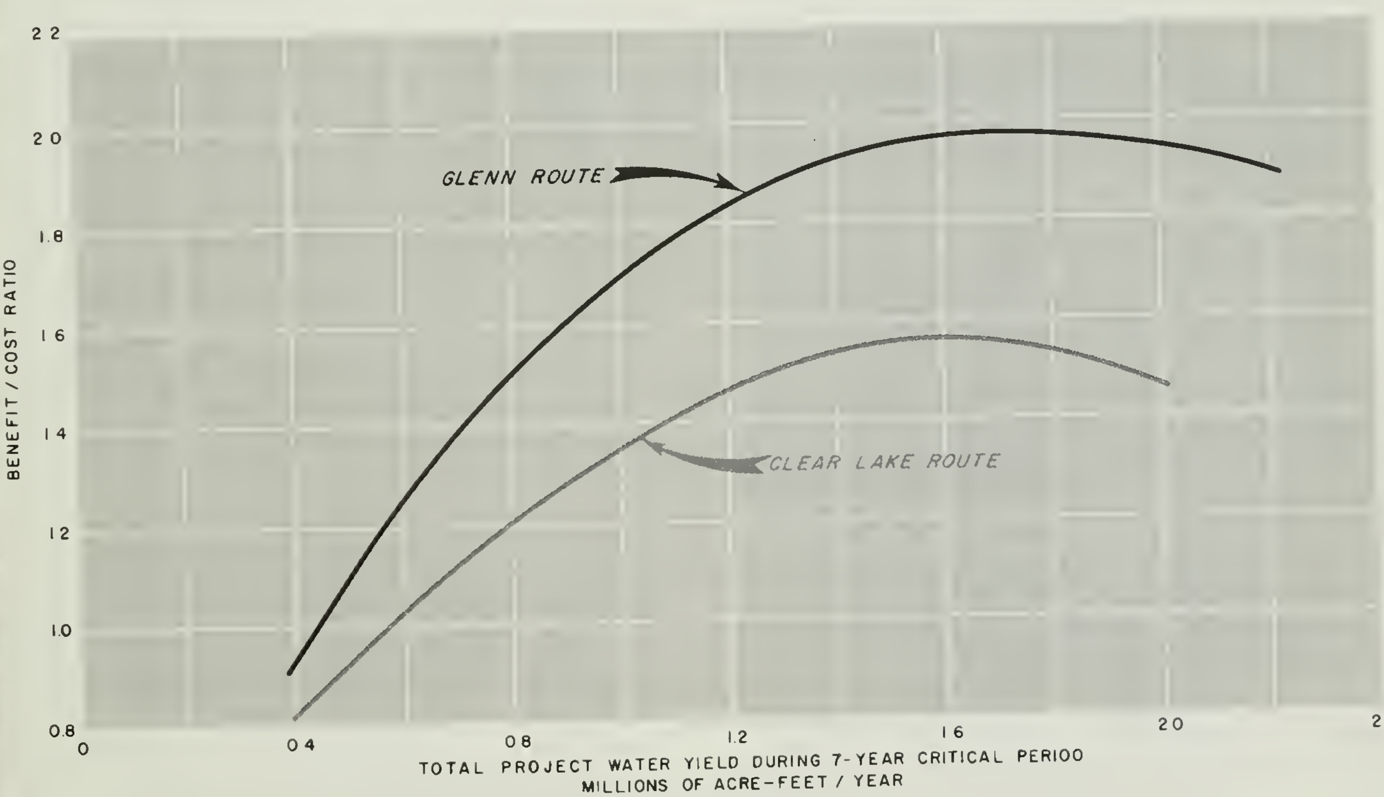
ILLUSTRATIVE BENEFIT COMPARISON BETWEEN ROUTES

Item	Clear Lake Route	Glenn Route
Total Annual Yield in acre-feet	1,600,000	1,600,000
Benefits		
Export Water Supply	$ 868,800,000	$ 985,500,000
Local Water Supply	115,170,000	-0- 1/
Recreation	58,390,000	20,760,000
Flood Control	44,360,000	15,930,000
TOTAL	$1,086,720,000	$1,022,190,000

1/ No local service area presently defined downstream on Rancheria Reservoir.



COMPARISON OF MINIMUM TOTAL PROJECT COSTS
FIGURE 5



COMPARISON OF BENEFIT-TO COST RATIOS
FIGURE 6

For illustrative purposes, a comparison of the benefits for typical projects on each conveyance route is presented in Table 1. The projects selected have comparable yields, about 1,600,000 acre-feet per year, and each represents an optimum project alternative at this level of development. The yield shown is the total average annual water yield during the critical dry period. It includes yield exported to the Delta and that used locally. It does not include water releases for fisheries preservation. For the Clear Lake Route about 212,000 acre-feet of yield would be attributable to the English Ridge Project; most of this water would ultimately be used locally.

The features of the Clear Lake Route alternative include a large Dos Rios Reservoir, English Ridge Reservoir, and Kennedy Flats Reservoir. The Glenn Route alternative is composed of large Dos Rios and Rancheria Reservoirs.

Comparison of Total Costs

The minimum total project cost which would be required to develop any given amount of total yield from 400,000 acre-feet per year to 2,000,000 acre-feet per year is shown in Figure 5. The total project cost is an item of great significance in economic comparison. If all else is equal, the least costly alternative is the better one. The lines shown are minimum values representing the least cost which would be incurred for a given scale of development. The present worth of operation, maintenance, power, and replacement costs are included.

For the Clear Lake Route, the line representing the least cost is defined for total yields below 1,600,000 acre-feet per year by combinations of a large dam at Dos Rios, impounding from 4,500,000 to 8,000,000 acre-feet, with either Wilson Valley or Kennedy Flats dams on Cache Creek. In other words, the more favorable plans for this route combine large storage on the Middle Fork with just enough storage on Cache Creek to provide effective reregulation of year-to-year flows.

For the Glenn Route, the line representing the least cost is defined by combinations of a small Dos Rios Reservoir for project yields below about 900,000 acre-feet per year, or a large Dos Rios Reservoir for yields above that, with either Rancheria or Paskenta-Newville reservoirs. Further detailed study will be required to determine the optimum combination of these reservoirs.

In all cases the total cost for the Glenn Route is from $90,000,000 to $240,000,000 less than that for the Clear Lake Route. As each route provides essentially the same services and functions as measured, for example, by the total benefits in Figure 4, the cost standard of comparison is of paramount importance in the route selection. An illustrative comparison of costs for the two typical project alternatives, as described in the preceding section comparing benefits, is presented in Table 2. Each project represents an optimum combination for the value of yield.

The costs shown include allowances for engineering, contingencies, and interest during construction. The estimated costs for operation, maintenance, and replacement are shown as present worth values and are set apart for each item. The present worths were computed using the standard 4 percent interest rate and 100-year period of analysis.

Comparison of Net Benefits and Benefit-to-Cost Ratios

Figures 6 and 7 measure the accomplishments of the two routes using the standard criteria developed for the economic evaluation of water projects. Figure 6 compares the maximum possible benefit-to-cost ratios of the alternative routes. The curves shown are envelope curves derived from consideration of the total project benefits shown in Figure 4 and the envelope lines of minimum total project cost shown in Figure 5. The total project benefits were divided by the minimum total project costs to derive the maximum benefit-to-cost ratios. This ratio has traditionally been used to choose between alternatives; the alternative having the higher benefit-to-cost ratio is economically more favorable. It may be noted that the Glenn Route would offer greater maximum benefit-to-cost ratios and that projects developing less than 450,000 acre-feet per year of yield on the Glenn Route and less than 560,000 acre-feet per year on the Clear Lake Route would not be economically justified.

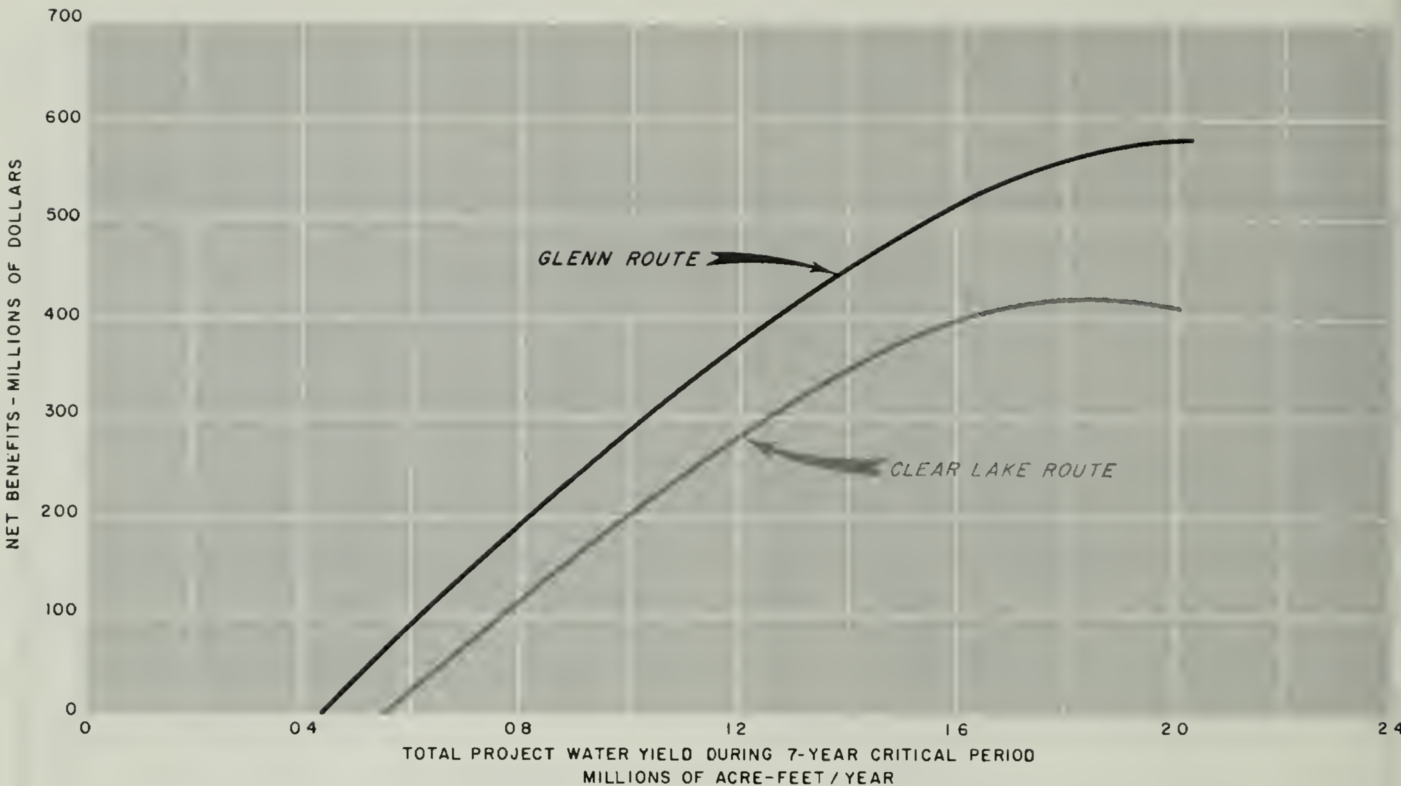
Figure 7 compares the maximum possible net benefits of the alternative routes. The curves shown are envelope curves derived by subtracting the minimum total project costs in Figure 5 from the total project benefits in Figure 4. The net benefits have traditionally been used to determine the optimum scale of development. As used in this context, however, they are also used to compare the alternative routes. The Glenn Route has greater maximum net benefits. It may be noted that the point of maximum net benefit on the Clear Lake Route is approximately 1,800,000 acre-feet per year of total yield, whereas the point of maximum net benefits has apparently not been reached for the Glenn Route for the range of sizes considered. However, more detailed studies of larger scale projects could be expected to redefine this curve and may show a point at which net benefits begin to decrease.

TABLE 2

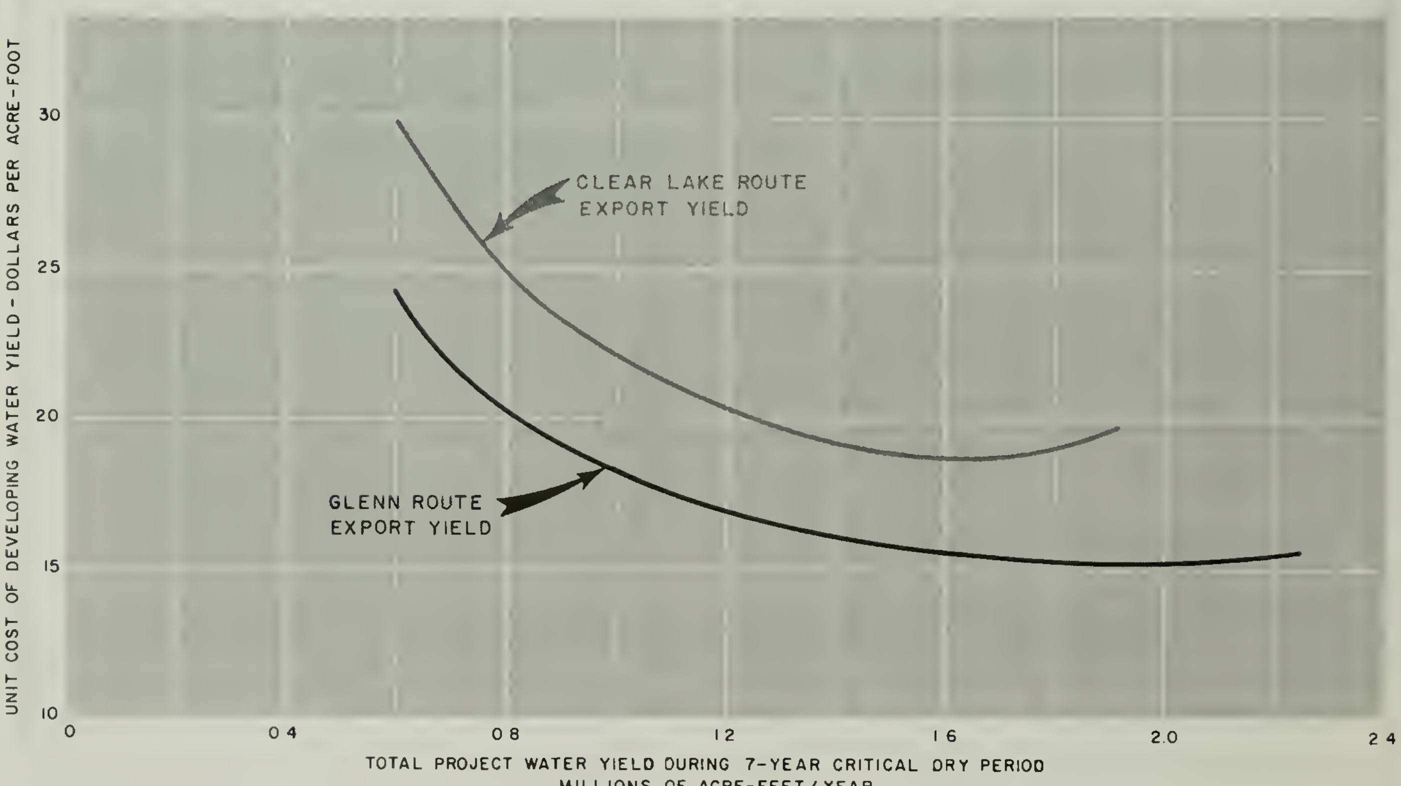
ILLUSTRATIVE COST COMPARISON BETWEEN ROUTES

Item	Clear Lake Route		Glenn Route	
Total Annual Yield in acre-feet	1,600,000		1,600,000	
Cost, in millions of dollars	Initial	OM&R 1/	Initial	OM&R 1/
Dos Rios Dam and Reservoir	$ 190.20	$ 17.40	$ 190.20	$ 17.40
Dos Rios Fish Hatchery	9.89	5.47	9.89	5.47
Dos Rios Recreation Facilities	4.48	6.09	4.48	6.09
Dos Rios Wildlife Mitigation	2.97	2.45	2.97	2.45
Dos Rios--Grindstone Tunnel			134.47	2.62
Elk Creek Pumping Plant and Tunnel	72.00	56.12 2/		
English Ridge Dam and Reservoir	104.70	9.56		
English Ridge Fish Hatchery	8.75	3.19		
English Ridge Recreation Facilities	7.97	14.17		
English Ridge Wildlife Mitigation	1.46	1.08		
Garrett Tunnel	61.00	1.05		
Clear Lake Outlet Modification	5.79	.56		
Kennedy Flats Dam and Reservoir	89.50	8.33		
Kennedy Flats Recreation Facilities	4.46	9.39		
Kennedy Flats Wildlife Mitigation	1.76	1.37		
Cache Creek Conveyance Channel	4.08	1.35		
Rancheria Dam and Reservoir			140.50	12.89
Rancheria Recreation Facilities			2.14	4.78
Rancheria Wildlife Mitigation			.09	.04
Stony Creek Conveyance Channel			7.00	2.30
Subtotal	$ 569.01	$ 137.58	$ 491.74	$ 54.04
TOTAL		$ 706.59		$545.78

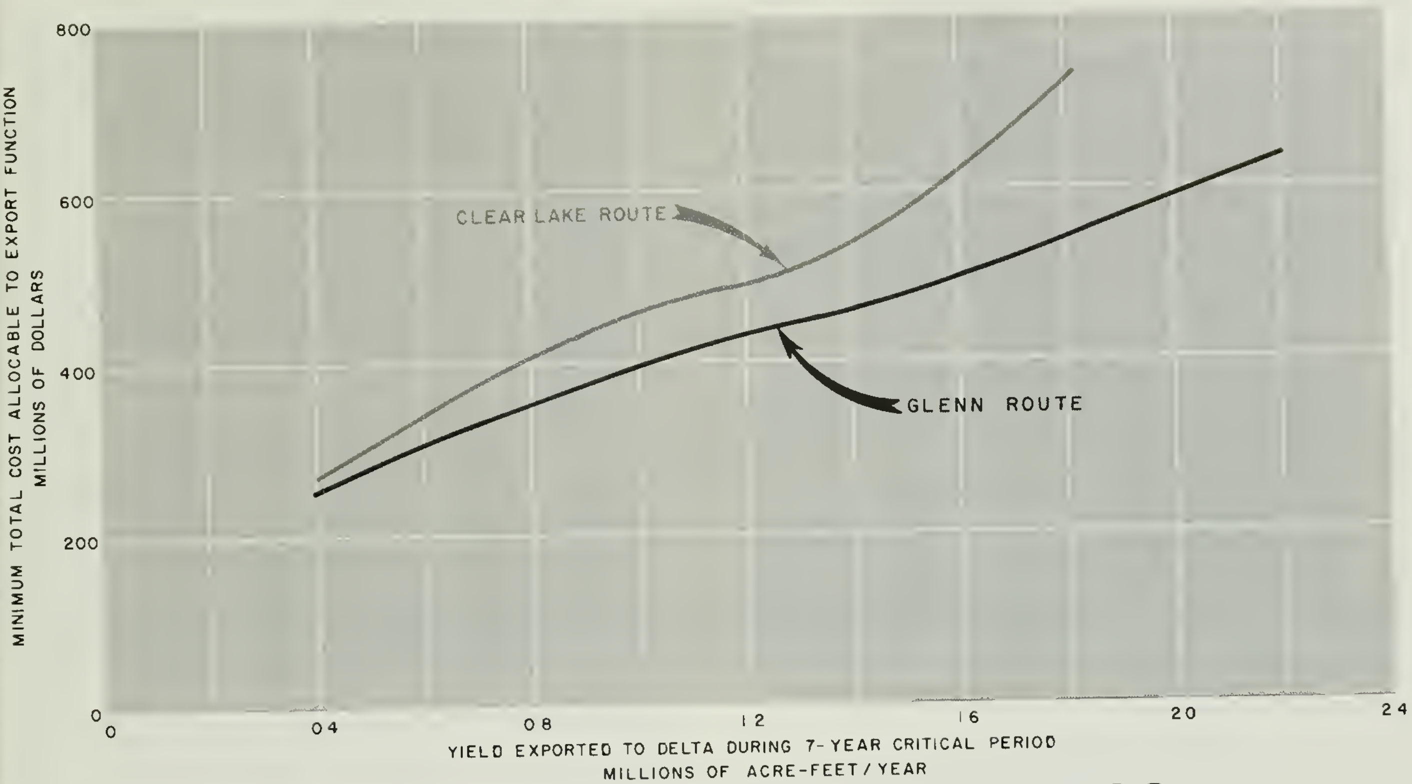
1/ Present worth, computed using 4 percent interest for 100 years.
2/ Includes cost of power for pumping over 100-year period.



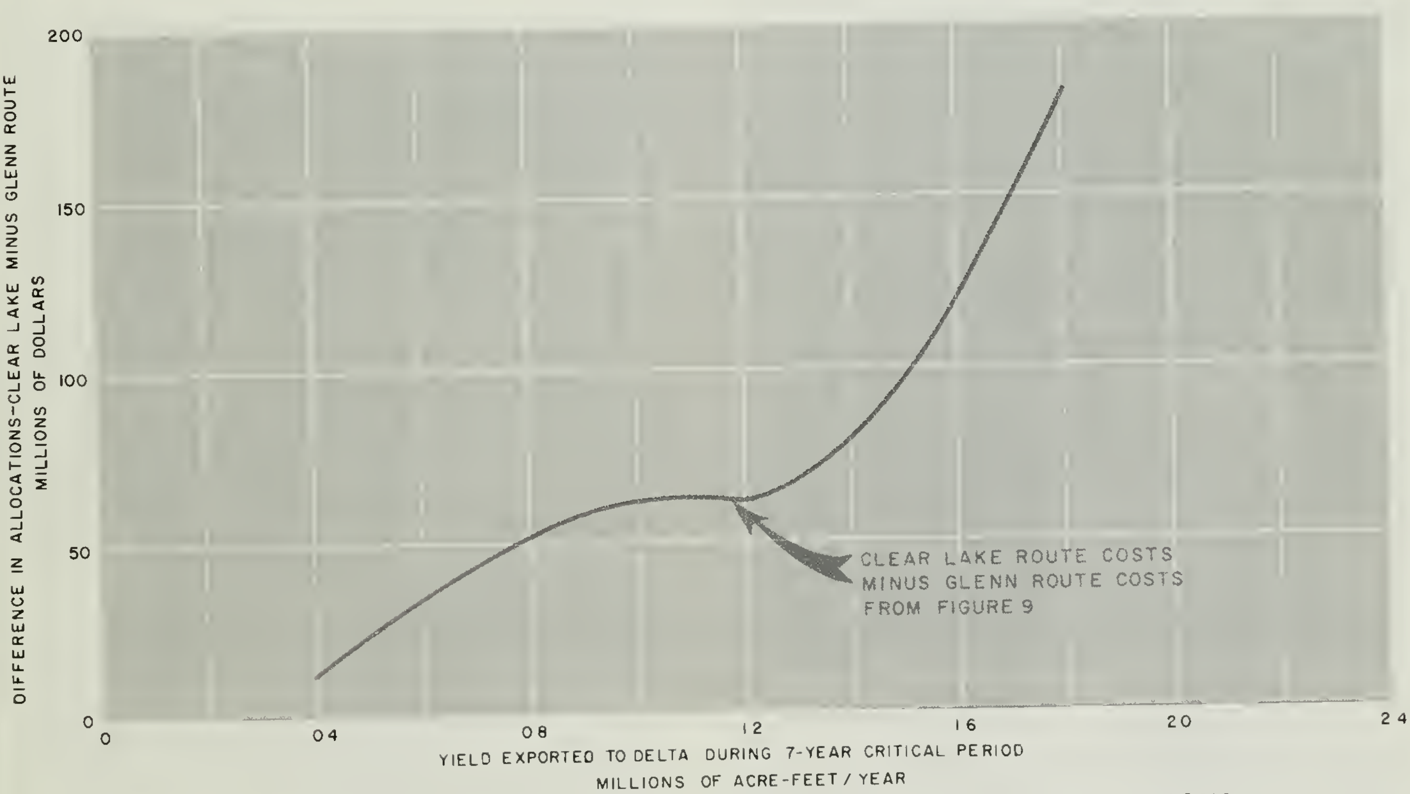
COMPARISON OF NET BENEFITS
FIGURE 7



COMPARISON OF UNIT COSTS OF DEVELOPING WATER YIELD
FIGURE 8



COMPARISON OF MINIMUM TOTAL COST ALLOCABLE TO EXPORT WATER FUNCTIONS
FIGURE 9



DIFFERENCE BETWEEN EXPORT WATER COST ALLOCATIONS TO CLEAR LAKE ROUTE AND GLENN ROUTE
FIGURE 10

Comparison of Cost to the Water Users

In the preceding sections, comparisons were made of overall project accomplishments. The comparisons in this section are more specifically of interest to the State Water Project. One of the major interests of project water contractors is in obtaining additional water at the least cost to themselves. The comparisons in this section show the Glenn Route would be less expensive to the State Water Project.

Unit Cost of Project Water Yield. Figure 8 depicts the minimum cost of each acre-foot of water developed and used from the Upper Eel River Development over the life of the project. This unit cost was obtained by dividing the present worth of the cost allocated to water supply by the present worth of the total number of acre-feet of water which would be sold to water users over the entire economic life of the project. The lines shown on the graph represent the minimum unit cost of delivering Upper Eel River Development project water to the Delta.

For local users of water, the unit cost of yield represents their allocated share of the costs of developing water as part of the larger overall plan of development. The cost of transporting the water from central points of delivery, such as Paskenta Reservoir or Clear Lake, must be added to this amount to determine the total costs for local users.

The unit cost of yield need not, however, represent the price of water to local users. By integrating the English Ridge Project or the Paskenta-Newville Project with the Central Valley Project, the Bureau of Reclamation may be able to provide irrigation water at or near Central Valley Project prices.

For the State Water Project, the unit cost of yield does not directly represent the price of water in the Delta. By integration of the Upper Eel River Development cost and yield with that for the present State Water Project, a new overall value of the Delta Water Rate will be determined for repayment purposes. The unit cost of yield, applied to the amount of acre-feet of water developed by the Upper Eel Project, represents an incremental cost of firming up the yield of the present State Water Project and of expanding it to include new water users.

Figure 8 shows that the minimum unit costs for projects on the Glenn Route are consistently from $3.25 to $6.00 per acre-foot of water less than the minimum unit cost for the Clear Lake Route. The amount of money represented by this differential in unit cost is shown in Figures 9 and 10.

Total Cost Allocated to Export Water Function. Figure 9 shows the minimum value of the total cost allocated to the function of export water supply for each route. This allocated cost is the amount which would have to be reimbursed by the present State Water Project contractors or by the present and supplemental water contractors where yields greater than the 900,000 acre-feet per year needed to meet present project commitments are concerned. It is the unit cost of water applied to the present worth of the annual amounts of water as shown on the horizontal scale.

Difference in State Water Project Allocations Between Routes. Figure 10 shows the difference between the curves of minimum allocated costs shown in Figure 9. It was obtained by subtracting the values on the Glenn Route curve from the corresponding values on the Clear Lake Route curve. This curve shows more clearly the minimum difference in costs to the State Water Project between the alternative routes. The Clear Lake Route would be more expensive for all sizes, as seen on this curve. The difference in cost varies between $30,000,000 and $185,000,000, with a sharp increase above a Delta yield of about 1,200,000 acre-feet per year.

As the most economical scale of development appears, at this time, to be a Delta yield of around 1,800,000 acre-feet, choosing the Glenn Route would result in over $180,000,000 in savings to the State Water Project.

Economy of Large Scale Development. The curves shown in Figures 8 and 9 may be used to give some preliminary indication of the economy in developing the Upper Eel River Development to a size larger than that required to provide water to compensate for depletions to the supply of the State Water Project. The amount required for the State Water Project is estimated to be 900,000 acre-feet per year by 2035. To provide this amount of water, a small development would be sufficient. But would such a development, which would only partly utilize the runoff of the Middle Fork Eel River, be the most economical one, considering statewide water needs and the California Water Plan?

The reimbursable cost of each acre-foot of water developed at a project size of 900,000 acre-feet per year would be a minimum of $19.20 for the Glenn Route as shown on Figure 8. Using the Glenn Route curve from Figure 9 this would amount to a reimbursable cost to the State Water Project of $375,000,000.

The reimbursable cost of each acre-foot of water developed at a project size of 1,800,000 acre-feet per year would be just over $15.00 for the Glenn Route as shown on Figure 8. This corresponds to a reimbursable cost of $550,000,000, using Figure 9.

Thus, the result of constructing a project to double the size in terms of water yield would be to reduce the cost of development of each acre-foot of water by $4.20. The total reimbursable cost would not double, but would increase by $175,000,000, or 48 percent, which represents the incremental cost of including 900,000 acre-feet of supplementary water yield into the project. To market this yield, supplementary water contracts could be made either with existing or with new contractors and the entire cost integrated into that of the State Water Project for repayment purposes, or the Bureau of Reclamation could contract for a portion or all of the supplementary yield to use in making up for their share of Delta water shortages.

On this basis, it appears that there would be significant economies to the water users in developing the Upper Eel River Development to the largest feasible size.

Other Factors in the Route Comparison

The purpose of this section is to discuss those other factors which had an influence on the route comparisons. They include water quality, flood control, future plans for the lower Eel River, local needs in the future, and operational considerations.

Water Quality

In recognition of the importance of the subject of water quality to the water users and to the people of the North Coastal area, a special investigation was conducted to survey the water quality aspects of the two routes. The results of this subsidiary investigation are summarized below.

Upper Eel River. The mineral quality of the water of the Eel River is excellent. Routing Eel River water through either route would not significantly harm the existing water quality and could bring about slight improvements at the expense of slight impairment to the quality of the imported water.

Clear Lake. At the time of the publication of Bulletin No. 136 there was considerable speculation and comment concerning the presumed beneficial effect the routing of Eel River water through Clear Lake would have upon many of the problems besetting the lake area. The results of the water quality investigation indicate that an eventual reduction in the boron concentration would be the only significant change in the quality of Clear Lake water due to importation of Middle Fork Eel River water, assuming that the intake structure to Garrett Tunnel is designed with the capability of selectively releasing water from a wide range of reservoir levels. Specifically, the conclusions were that:

1. Based on operational studies made on the proposed conveyance system from the Middle Fork Eel River, the existing turbidity within Clear Lake could be increased during the early part of the summer because the turbidity level of the water imported during the winter and early spring months could be much greater than that present in the lake.

2. The mineral quality of the lake would be improved slightly as the boron concentration is lowered. The quality classification would be improved from Class 2 to Class 1 for irrigation use and would then be rated as excellent for most purposes.

3. Addition of Eel River water would lower the present water temperature on the average about 2° F. in August. This small decrease in the temperature of the water, which presently reaches 79° F., would not significantly help nor aggravate the present water quality situation in Clear Lake.

Cache Creek. Surplus Eel River water diverted to the Sacramento River through Clear Lake could be reregulated by construction of a large reservoir on Cache Creek, the natural drainage of Clear Lake.

Tributaries to Cache Creek downstream of Clear Lake are highly mineralized, being moderately hard and having high boron concentrations. Present releases from Clear Lake dilute these inflowing waters with only a slight overall increase in mineral concentrations in the Cache Creek water. Additional releases would further dilute inflowing water.

The mineral quality of water released from a proposed reservoir on Cache Creek would be Class I for irrigation and suitable for most purposes. The effect of this water on the mineral quality of the Sacramento River would not be significant.

Biologically, a reservoir built on Cache Creek in the vicinity of the Wilson Valley site would undoubtedly be subject to algae blooms, particularly in the shallow portions. It is not expected that algae conditions similar to those that occur in Clear Lake would develop in the deeper main body of the reservoir.

The depth of the reservoir would be sufficient to allow control of temperature of water released, provided multiple level outlets are installed.

Lake Berryessa. While the importation of Eel River water will bring about little change in Clear Lake, routing it through an enlarged Lake Berryessa could bring widespread changes to the lake's present ecology. The warm Clear Lake water which would be brought into the lake along with the Eel River water, could possibly create algae problems in the shallow upper half of Lake Berryessa and damage the present cold water trout fishery in the lake and downstream in Putah Creek.

Glenn Complex. The present water quality of Thomes and Stony Creeks is excellent. Though the water is moderately hard and more mineralized than Middle Fork Eel River water, the mixing of these will result in a water that will be excellent and usable for most purposes.

No particular problems are anticipated with water quality control in these reservoirs. Turbidity contributed by Grindstone and Thomes Creeks will cause portions of Rancheria and Paskenta Reservoirs to be turbid near the surface water inlets to the reservoirs during part of the year. Also, turbidity can be expected during the spring and early summer due to the turbidity level of the water imported during the winter and early spring months from the Middle Fork Eel River.

Because of the depth of these reservoirs and the quality of the water entering them, the growth of plankton and algal organisms will be limited. Some nuisance growths may occur in shallow inlet portions of the reservoir, but large growths are not anticipated. Control of the Clear Lake variety of gnats, which presently exist on Black Butte Reservoir, may be a problem, although it is doubtful if it will ever be as acute as the Clear Lake problem.

Flood Control

Upper Eel River. The construction of Dos Rios and English Ridge Reservoirs will provide some flood control for the lower Eel River. In conjunction with the proposed Eel River Delta levees, the two dams would provide protection in the Eel River Delta against a flood equivalent to the disastrous one of December 1964, which is the greatest ever recorded.

More than two-thirds of the flood control contribution from the Upper Eel reservoir developments would come from a large Dos Rios Reservoir, which would be capable of absorbing the greatest floods possible on the Middle Fork Eel River.

Flood control on the Middle Fork Eel River, although important to the Eel River Basin, was not an important factor in the comparison of the routes as the Middle Fork features are common to both routes. It will benefit the State, however, through the federal flood control contributions, which will reduce the project costs which must be repaid by the water contractors and by the State as a whole.

Clear Lake - Cache Creek. Control of the occasional floods which cause widespread damage in the low-lying areas around Clear Lake and on lower Cache Creek has long been considered desirable. Reservation of about 165,000 acre-feet of the storage capacity of the Cache Creek Reservoir and enlargement of the outlet channel to Clear Lake have been included as part of the works envisioned for the Clear Lake Route plans.

It may be possible, however, that the same result could be obtained independently at a low cost by enlargement of the outlet channel (necessitating modification of the Gopcevic and Bemmerly decrees)* which would solve the larger problem of flooding around Clear Lake, and by construction of either Indian Valley Dam and Reservoir on North Fork Cache Creek, or a small flood control reservoir impounding about 200,000 acre-feet of water at the Wilson Valley site on Cache Creek downstream from the lake.

The Indian Valley Project, proposed by the Yolo County Flood Control and Water Conservation District, is a good possibility for construction in the near future. By operating this dam and reservoir for flood control along with its main purpose of water conservation, and enlarging the outlet chan-

* Bemmerley v. Lake County, 55 Cal. App 2nd 829, 132 P. 2nd 249 (1942)
Gopsevic v. Yolo Water and Power Co. (California Superior Court in and for County of Mendicino, 1919)

nel to Clear Lake, the flood control problems of the area could be abated. This project would, incidentally, take care of up to 20,000 acre-feet per year of the supplemental water requirements of service areas on lower Cache Creek.

No distinct advantage in these comparisons, as far as flood control is concerned, is apparent for the Clear Lake Route because the benefits of flood control could be provided at a reasonable cost without routing Middle Fork Eel River water through Clear Lake.

Thomes Creek. Flood protection along Thomes Creek, which joins the Sacramento River a few miles below Red Bluff, can best be achieved through construction of the Paskenta-Newville Project, currently under study by the Bureau of Reclamation and the Department of Water Resources. This project is envisioned as an independent project, but could be integrated into the Upper Eel or Trinity River Developments. The detailed studies of Phase II of the Advance Planning Program will determine if it is to be integrated into the Upper Eel River Development or developed as a unit of the Central Valley Project.

Future Plans for Lower Eel River

The U. S. Corps of Engineers is currently studying the possibility of constructing large dams and reservoirs on the lower Eel River. These would be multiple-purpose projects to provide flood control and recreation for the Eel River Basin and water for export to other areas of the State. According to preliminary timetables established in Bulletin No. 136 and in Bulletin No. 160-66, "Implementation of the California Water Plan", they are scheduled to be constructed after development of the Trinity River. An average of 1,000,000 acre-feet per year of water from the lower Eel River Reservoirs would be pumped upstream to Dos Rios Reservoir. It would then be either pumped about 350 feet higher to English Ridge Reservoir or regulated and released to flow by gravity through the Dos Rios--Grindstone Tunnel to Rancheria Reservoir and the Sacramento River.

Routing lower Eel River water through Dos Rios Reservoir would require, for the Glenn Route, only a minor incremental increase in the diameter of the Dos Rios--Grindstone Tunnel from 14 feet to about 16 feet. The reregulatory capacity of a large Dos Rios Reservoir would allow the tunnel to be used to near capacity all of the time, thereby economizing on the tunnel size required.

The Clear Lake routing, on the other hand, would require an addition of a minimum of 85,000 acre-feet per month capacity to the underground pumping plant, penstock, and tunnel of the Elk Creek pumping system. As the capacity necessary to handle Middle Fork flows would vary from 60,000 to 110,000 acre-feet per month, this would mean essentially doubling the capacity of the Elk Creek system. Garrett Tunnel capacity would also have to be increased by a minimum of 85,000 acre-feet per month. The following table illustrates the additional incremental cost due to pumping the lower Eel River water through English Ridge instead of diverting from Dos Rios Reservoir by gravity in the Glenn Route.

The comparative effect on the incremental costs of possible hydroelectric power generation has not been included. By routing the water through Clear Lake a maximum power head of about 750 feet could be utilized at Blue Ridge Reservoir on Cache Creek. Routing the water through the Glenn Complex would allow a maximum power head of about 400 feet to be utilized. The net revenues from such power generation however, would

TABLE 3

COMPARISON OF INCREMENTAL COSTS FOR LOWER EEL RIVER WATER

	Clear Lake Route	Glenn Route
Initial Cost Increment	$42,000,000	$20,000,000
Operation, Maintenance, Power, and Replacement Cost Increment	41,000,000	400,000
TOTAL	$83,000,000	$20,400,000

probably not significantly change the cost differential. The effect of hydropower will be studied in detail in the Eel River Basin Master Plan program.

Pumping lower Eel River water through English Ridge would mean an additional incremental cost of approximately $62,000,000 throughout the project life.

Local Area Water Needs

English Ridge Project. State and federal water demand and reservoir operations studies show that the English Ridge Project is capable of providing enough water to satisfy the ultimate needs around Clear Lake and in the Upper Putah Creek Basin. As the English Ridge Project, proposed and under study by the U. S. Bureau of Reclamation, is not dependent upon the routing of Middle Fork Eel River water, it could be constructed for this purpose and possibly integrated into the Federal Central Valley Project.

Paskenta-Newville Project. In addition to providing much needed flood control along Thomes Creek, the Paskenta-Newville Project, if coordinated with the Central Valley Project--State Water Project system, could develop up to 350,000 acre-feet per year of dry period yield through storage of surplus flows during wet periods. Local water needs in the Thomes Creek and Newville service areas would be met by releases from each reservoir. A need for up to 37,500 acre-feet of water has been estimated. The remaining storage space in Newville Reservoir could be reserved for Trinity or Eel River imports.

Elk Creek Pumping Plant

The water from the Middle Fork Eel River must be lifted by pumps in the Elk Creek Pumping Plant to transport it to English Ridge Reservoir. The pump lift would vary from 100 to 350 feet, depending upon the water surface elevation of Dos Rios Reservoir. This large variation in the water level of a large Dos Rios Reservoir, which is an absolute requirement for the Clear Lake Route, would present complicated problems in the design of pumps and motors. In addition, the variation in water level would dictate the provision of an underground pumping installation. Although in general geologic conditions in the area are not suitable for underground installations, a possibly suitable site has been located for such a plant, but subsurface exploration to confirm the suitability of the area has not been possible.

The necessity of pumping the water to English Ridge Reservoir from Dos Rios Reservoir introduces a severe constraint upon the design of the features of that route. To avoid wasting water, either very large storage on the Middle Fork must be constructed to provide regulating capability, or the capacity of the Elk Creek pumping plant and tunnel must be increased. This is illustrated in Chapter 4, under "Reservoir Storage Requirements".

Mitigation of Damage to Fisheries and Wildlife Habitat

The construction of dams and reservoirs would inundate and block access to salmon and steelhead spawning areas and destroy wildlife habitat in the reservoir areas. The following table illustrates the cost of mitigating for this damage. Mitigation is required by law. The tabular values include the cost of construction and operation of fish hatcheries for salmon and steelhead at the Dos Rios and English Ridge damsites and the cost of developing and maintaining replacement lands for wildlife.

For comparative purposes, the cost of mitigation for the Middle Fork Eel River area is separated in the table. It amounts to $20,780,000. The remaining mitigation on the

TABLE 4

COMPARISON OF MITIGATION COSTS BETWEEN ROUTES

	Clear Lake--Cache Creek Route Total Cost	Glenn Route Total Cost
Middle Fork Eel only	$20,780,000	$20,780,000
Additional Features	17,610,000	130,000
TOTAL	$38,390,000	$20,910,000

Glenn Route for Rancheria Reservoir is only $130,000, while that for the Clear Lake Route, including English Ridge Reservoir, is $17,610,000.

Operational and Staging Considerations

Two other important considerations in comparison of the routes were the ease of operation of the project and its integration into the present and planned projects making up the California Water Plan, and the possibility of staging construction of major features to spread the expenditure of capital for construction over a period of years.

The alternative routes were compared both qualitatively and by examination of the operational studies used to determine water yields. The results of this comparison have shown that the Glenn Route is simpler and more flexible operationally. The provision of two large reservoirs, Dos Rios and Rancheria, connected by a single gravity-flow tunnel would result in a system that would be simple to operate, efficient, and relatively flexible. Later integration of lower Eel River developments would be relatively inexpensive compared to the Clear Lake Route and would present no special operational problems. Routing of the water through the Glenn Complex would also be in conformance with the objectives of the California Water Plan. Use of the vast storage capabilities of Rancheria and Newville Reservoirs to reregulate and store the flows of the Eel, Trinity, and Klamath Rivers would provide one central hub or collection and disbursement center through which all of the imported surplus North Coastal waters would pass. The operational advantages to the statewide water development system would be very great.

On the Clear Lake Route, by comparison, the necessity of pumping the water from Dos Rios to English Ridge Reservoir and the necessity of operating a large lake and several reservoirs in a chain, each with its own large local inflow, would result in a system which would be relatively inefficient from a power and water conservation standpoint. Operationally, it would also be less flexible than the Glenn Route, particularly in integrating into the present system, due to the operational restraints imposed by the necessity of pumping from Dos Rios Reservoir. The requirement of releasing large amounts of water during the critical period, versus reduced amounts during wet periods, makes efficient design and operation of a pumping plant very difficult. The pumping plant must be designed to pass the largest flows required, and power contracts must be made for the capacity in kilowatts to pump this amount, yet for most years the pumping plant would operate at less than full capacity.

Insofar as the California Water Plan is concerned, the service of local water needs in the Clear Lake--upper Putah Creek areas, which was identified in that plan, is keyed presently to English Ridge Reservoir, under study by the U. S. Bureau of Reclamation. This project could be built to serve these local interests independently of the Middle Fork Eel routing. This would satisfy the area water service objective and allow the overall economic objective of choosing the alternative least costly to the water users to be met.

With regard to the possibilities of staging construction, preliminary studies indicate that it may be possible to devise some effective means of staging the Glenn Route by initially constructing Dos Rios Reservoir and the tunnel and following that as the need develops by the reservoir(s) of the Glenn Complex.

On the Clear Lake Route, preliminary studies have not been successful in devising a scheme for staging; the problems associated with the long chain of reservoirs and the pumping plant would probably require all elements to be completed at nearly the same time.

CHAPTER 3. PLANNING BACKGROUND

This chapter describes planning aspects which are significant in the formulation process. These aspects are the development's relationship to the State Water Project and state-federal cooperative planning. The following sections discuss these aspects.

State Water Project

Legal and Financial Aspects

The legal basis for the Upper Eel River Development is contained, basically, in two documents. These are the California Water Resources Development Bond Act, known popularly as the Burns-Porter Act, which was passed by the Legislature in 1959 and approved by the voters in 1960, and the Department's Standard Provisions for Water Supply Contracts.

The Burns-Porter Act authorizes the issuance of $1,750,000,000 of water bonds for the construction of initial State Water Project facilities and appropriates money in the California Water Fund for the purposes of the Act. As money is spent from the California Water Fund for the construction of initial project facilities, a like amount of unissued water bonds is reserved or offset for future expenditures for additional facilities. The Upper Eel River Development is the first additional facility of the State Water Project. As of the publishing date of this report, the "offset bond" fund amounted to approximately $160,000,000, and it is expected to increase by about $11,000,000 annually as further expenditures are made from the California Water Fund.

The legal structure for marketing the water developed by the State Water Project is the Department's Standard Provisions for Water Supply Contracts. The Department has a legal obligation to conserve, transport, and deliver the minimum yield of the project, 4,230,000 acre-feet per year. The repayment structure of the standard provisions provides for an increase in future water rates as necessary to repay the cost of the additional conservation facilities needed to sustain the minimum yield.

Under this concept, a single rate for water from the Delta is charged in recovering the costs of all conservation facilities necessary to develop the project water supply. This rate applies to present and future water supply contractors of the State Water Project. The effect of this principle is to average the lower unit costs of initial conservation features with the higher unit costs of later conservation facilities, such as the Upper Eel River Development. This places both present and future contractors on an equal basis.

The facilities of the Upper Eel River Development will not be limited strictly to sustaining the water supply in the Delta. The Burns-Porter Act specifies that the facilities may be multiple-purpose, including provisions for flood control, local water service and other uses. Article 16 (d) of the Standard Contract Provisions, referring to the construction of additional facilities, provides for the construction of "related appurtenant facilities necessary and desirable to meet local needs". Service to local areas was included as a project purpose in the route selection studies although the total amount would be relatively insignificant compared to the large quantities of surplus flows to be exported. The assumption used throughout these studies was that the U. S. Bureau of Reclamation would market local water for irrigation at the lowest possible price, in accordance with its policies.

Operational Considerations

The Department will operate the State Water Project in accordance with the Delta Pooling Concept. This concept recognizes the Sacramento--San Joaquin Delta as the central point through which all surplus flows originating in the Sacramento and San Joaquin Valleys must drain, and as a focal point for the export and distribution of this surplus water to water deficient areas in the southerly portions of the State. Water to meet demands in areas of deficiency will come from surplus flows now wasting to the ocean during the winter and spring months, augmented by releases from the major storage reservoirs in the Central Valley.

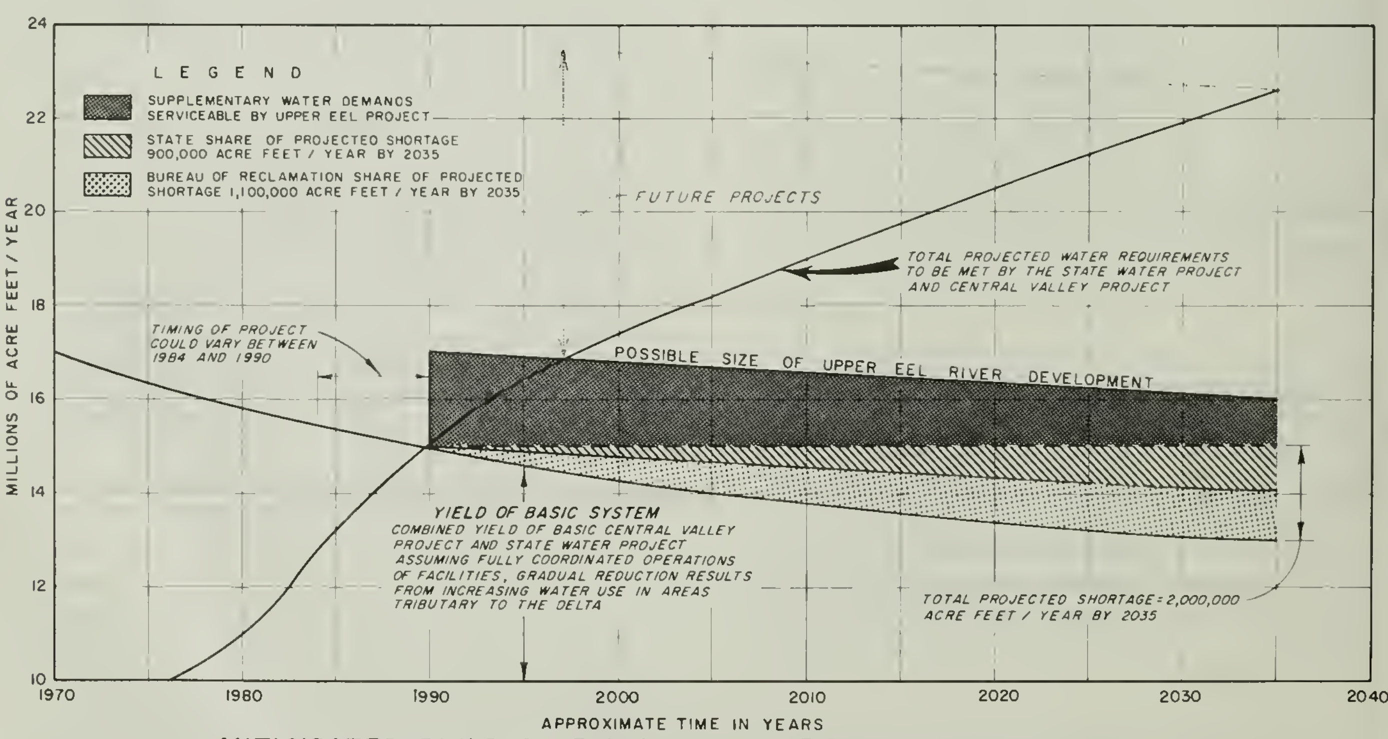
The construction of projects to meet the buildup of demands for water in areas tributary to the Delta will deplete the remaining surplus supply in the Delta upon which the State Water Project and the Central Valley Project depend. The California Water Code provides that all areas in and tributary to the Sacramento--San Joaquin River system will be guaranteed the legal right to tributary water for all beneficial uses as their needs develop.

Under the Delta Pooling Concept, as surplus flows to the Delta are gradually diminished, additional conservation facilities would be constructed to augment the depleted water supply. The Upper Eel River Development has been designated as the first additional project conservation facilities of the State Water Project.

Additional project conservation facilities are defined in the Standard Provisions for Water Supply Contract as the facilities needed to prevent a reduction in the minimum project yield, as future development within the Central Valley depletes the water supply available to the State Water Project. The required timing and sizing of additional conservation facilities are based upon estimates of the future yield which could be obtained from the initial conservation facilities; that is, from Oroville and San Luis Reservoirs. Simulated operation studies of the State Water Project--Central Valley Project system have been made for projected future levels of development, each succeeding level representing continued growth of urban and agricultural development within the Central Valley.

From the system operation studies, it has been determined that between 1985 and 1990 additional water supplies will be needed to maintain the minimum project yield during the occurrence of a critically dry period similar to the historic 1928 to 1934 period. During periods of average water supply conditions in the Central Valley, the minimum project yield could be maintained by the initial conservation facilities.

For planning purposes, the size of additional conservation facility required by the project is based upon the projected level of development in the year 2035. This corresponds to the estimated end of the project repayment period. The amount of additional water supply which the project would require at that level of development is currently estimated to be 900,000 acre-feet per year. This is an average annual amount required over the historical critical 7-year dry period and represents the State Water Project's share of the potential 2,000,000 acre-foot per year shortage in the combined State Water Project--Central Valley Project system as shown in Figure 11. The proportionate sharing of projected shortages was determined by the May 16, 1960, agreement between the Department of Water Resources and the Bureau of Reclamation.



ANTICIPATED BUILDUP OF STATEWIDE DEMAND SERVICEABLE BY STATE WATER PROJECT AND CENTRAL VALLEY PROJECT
FIGURE 11

Future Water Demands

The future water demands of the State as a whole will increase beyond those which can be satisfied by the present system with its already authorized additions. This increase in "open system" demands will be met in part by local projects and by certain independent federal projects. Much of the increase in demand will have to be met, however, by expansion of the State Water Project and Central Valley Project.

Figure 11 shows the anticipated buildup of statewide demands serviceable by the Central Valley Project and the State Water Project, along with the projected delivery capability of the combined systems. The combination of increasing needs for water with steady depletion of the available supply in the Delta results in an unprecedented demand buildup rate.

Preliminary results from the route selection studies have indicated that a facility sized to meet only the needs for an additional conservation facility would be less than optimum size, relative to potential development of the Middle Fork Eel River and the associated reregulatory storage in the Sacramento Valley. These studies show that an Eel River project of increased scale could provide a new firm yield substantially greater than that needed to maintain the minimum project yield. The amount needed for this purpose will be 900,000 acre-feet per year by 2035 as shown on Figure 11. Thus formulated, the Eel River project could function both as an "additional" and as a "supplemental" conservation facility. The latter is defined in the standard provisions as a facility which would supply water in addition to the minimum project yield. The economies of scale obtained from this larger development would result in a lower cost associated with the function of maintaining the minimum project yield. This was demonstrated briefly in Chapter 2 in the section entitled "Economy of Large Scale Development".

The supplemental water supply developed by a large-scale Upper Eel River Development could be used to meet one or more of several projected needs. These needs include possible future contracts for water supply from the State Water Project, provision of water supplies to offset the Central Valley Project's share of projected depletions, or future water demands on the Central Valley Project. Under the latter two possibilities, the development could be operated as a joint use facility with the Bureau of Reclamation, similar to the San Luis facilities. The current interagency planning for the Eel River is directed toward exploring such joint development.

The initial facilities of the State Water Project are designed to meet water demands in the project service areas to the year 1990. Forecasts presented in the Department's Bulletin No. 160-66, indicate that the combined demands on the State Water Project and Central Valley Project may increase by about 6,000,000 acre-feet between 1990 and 2020. It is estimated that possibly 2,500,000 to 3,000,000 acre-feet of these demands could best be met through development of supplemental conservation and conveyance facilities of the State Water Project. This would comprise, in essence, a second phase of the project. It would thus appear that the full yield potential of the Upper Eel River Development could be utilized.

State-Federal Cooperative Planning

Interagency Activity

The California State-Federal Interagency Group was organized in 1958 to facilitate coordination and cooperation among federal and state water development agencies. The group's members are: The Department of Water Resources, the U. S. Bureau of Reclamation, the U. S. Corps of Engineers, and the U. S. Soil Conservation Service. The interagency group and its subgroups function on a statewide basis. One of the more intensive cooperative efforts has been in regard to the development of the Eel River.

In January 1964, a special interagency work group was created to work out the details of a joint planning program for the Upper Eel River Development. Subgroups were established within this framework for each of the technical study disciplines such as hydrology, geology, designs and cost estimates, recreation, water quality, fish and wildlife, rights-of-way, and hydroelectric power. Through frequent meetings of these subgroups, there has been a free exchange of basic data and ideas. As a result of the cooperative effort, an interagency joint work program to formulate a comprehensive plan of water resources development for the Eel and Mad River Basins has been formally agreed upon by the principals of the member agencies. This agreement assigns responsibilities for the conduct of planning studies for specific subbasins, projects, and project functions.

In the Middle Fork Eel River planning studies, the agreement calls for the State and Corps of Engineers to have joint responsibilities in project formulation, financial studies, and report preparation. Joint responsibility in these functions is necessary because either the State or the Corps of Engineers may serve as the constructing agency. In the event of state construction, it would be necessary for the State to formulate the project and to demonstrate the project's financial feasibility on the basis of interest rates available to the State. Although the Department and the Corps of Engineers share the primary responsibility for project formulation on the Middle Fork Eel River, the other two agencies will participate in formulation decision making.

Eel River Basin Master Plan

Out of the interagency agreement has come the interagency responsibility for formulation of a master plan for water and related land resource development in the Eel and Mad River Basins. The studies made by the individual agencies on the segments for which they have responsibility will be integrated into a comprehensive plan for water conservation, flood control, fisheries preservation and enhancement, recreation, and other purposes for the general welfare of the area and State. The joint master plan report is scheduled for completion in 1970.

Federal Participation

There is a possibility that it would be advantageous to the State and to the Federal Government if the Upper Eel River Development were constructed jointly by the State and the Federal Government. This could be implemented either by means of a direct federal-state partnership agreement similar to the one worked out on the San Luis Project or by federal construction and financing under the Water Supply Act of 1958. This Act provides for delayed repayment provisions which could be advantageous to the State. The portion of the total project cost allocated to water supply may be subdivided into initial and future water supply portions. Repayment of the portion of the cost allocated to initial water supplies may be delayed for 10 years or until first use of the water, with no interest charged until repayment begins. Of the portion allocated to future water supplies, repayment of an amount equal to 30 percent of the total project cost may be delayed until first use of the water. Interest on this amount would be charged only after the first 10 years of project operation. Both principal and interest would have to be repaid within 50 years of first use of the water for future supplies, or the economic life of the project, whichever is shorter. Standard repayment contracts would be necessary for that part of the allocation to water supply not covered by the Act.

In the area of project planning, the Bureau of Reclamation is conducting a feasibility-level planning study on the English Ridge Project on the upper main Eel River. The English Ridge Project can provide water sufficient to meet the ultimate serviceable demands of the Clear Lake--Cache Creek and upper Putah Creek areas with surplus going to the Central Valley Project. The physical features of this project are described in Chapter 5. The Bureau's feasibility report is scheduled for completion in December 1967.

The Corps of Engineers is conducting a comprehensive basin-wide study for water resources development in the Eel River Basin. They are giving special emphasis to the possibilities for the construction of dams on the lower Eel River and to the construction of conservation works on the Middle Fork Eel River. Their interim survey report on the Middle Fork Eel River is scheduled for December 1967, an interim report on the lower Eel River for December 1968.

The Soil Conservation Service is conducting a watershed management study of the entire Eel River Basin. The purpose of this basin-wide survey is to identify and evaluate sediment sources within the basin and to formulate measures for reducing this sediment production. Their field work on the Middle Fork Eel River has been completed and work is underway in other portions of the basin; their report is scheduled for completion in 1968.

On the west side of the Sacramento Valley, the Bureau of Reclamation is conducting a feasibility-level study of the Paskenta-Newville Project, which would provide local water service and flood control as well as storage for future imported water. Their report on this investigation is scheduled for completion in December 1967.

Comments of Federal Agencies

The U. S. Bureau of Reclamation, Corps of Engineers, and Soil Conservation Service have cooperated with the Department in the planning program to select the conveyance route and have provided data for use in the analysis of the alternative routes.

The three federal agencies have provided letters in which they state their concurrence with the conclusions of this report and the selection of the Glenn Route for conveyance of Middle Fork Eel River water to the Sacramento Valley.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
2020 Milvia Street
Berkeley, California 94704

June 12, 1967

Mr. William R. Gianelli, Director
Department of Water Resources
P.O. Box 388
Sacramento, California 95802

Dear Mr. Gianelli:

In response to Mr. Steiner's letter of May 12 and Mr. Dukleth's letter of June 7 transmitting Bulletin No. 171 "Upper Eel River Development -- Investigation of Alternative Conveyance Routes" and supporting enclosures, this is to advise you of our concurrence in your Department's conclusions as a result of the very extensive studies made in conjunction with the studies of alternates for route selection.

Over recent years your staff has periodically made reports to our group on the work accomplished by your Department, and have reviewed to the extent practical the many reports covering the geology, borings, cost estimates, etc. on the various alternate routes studied. We appreciate your furnishing us copies of these studies and commend your Northern District on the professional approach and adequacy of their investigation of these many alternates and the technical problems associated with each.

Sincerely yours,

T P Helseth

T. P. Helseth
State Conservationist

UNITED STATES
DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REGIONAL OFFICE, REGION 2
P. O. BOX 15011
SACRAMENTO, CALIFORNIA 95813

IN REPLY REFER TO: 2-704

JUN 14 1967

Mr. William R. Gianelli, Chairman
California State-Federal Interagency Group
Department of Water Resources
1416 Ninth Street, Room 1123-15
Sacramento, California 95802

Dear Mr. Gianelli:

Receipt is acknowledged of the revised foreward and conclusions of your proposed draft report, Bulletin No. 171, "Upper Eel River Development--Investigation of Alternative Conveyance Routes," which were furnished us by Mr. Dukleth's June 7, 1967, letter. The foreward and conclusions, as revised as a result of the California State-Federal Interagency Group discussions held in your office on June 5, are acceptable to our office. We note the primary conclusion that the Glenn Route is the superior route for diversion of Middle Fork Eel River water. Furthermore, you conclude that the English Ridge Project on the Upper Main Eel River is a logical source of water for the Clear Lake-Upper Putah Creek areas.

Your draft report is predicated upon various assumptions and projections concerning Central Valley Basin water supplies, build-up of demands, and future operations of Federal and State project units. We have been unable to consider in detail the assumptions and evaluations relating to water supply and use; however, we consider these elements to have no particular bearing on your findings concerning route selection. We, along with the other agencies, will address ourselves to such considerations during the formulation and evaluation of a Master Plan of Development for the Eel and Mad River Basins which is programed for completion by our Interagency Group within the next three years.

We appreciate having had an opportunity to review and comment on your proposed report and for the courtesies which you have extended us in this regard.

Sincerely yours,

R. J. Pafford

R. J. Pafford, Jr.
Regional Director

DEPARTMENT OF THE ARMY
SOUTH PACIFIC DIVISION, CORPS OF ENGINEERS
630 Sansome Street, Room 1216
San Francisco, California 94111

IN REPLY REFER TO

SPDVN

26 June 1967

Mr. William R. Gianelli, Director
Department of Water Resources
Resources Agency of California
P. O. Box 388
Sacramento, California 95802

Dear Mr. Gianelli:

Reference is made to the California State Federal Interagency Group meeting held on 6 June 1967 in the office of the Department of Water Resources.

At this meeting representatives of the Northern District of DWR made a presentation of their findings in Bulletin No. 171, Upper Eel River Development, Investigation of Alternative Conveyance Routes.

After a discussion of the report draft, a set of conclusions dated 7 June 1967 were also discussed. Mr. John Teerink, chairman for the meeting, requested agency views and comments on the conclusions. Based on information furnished in the draft of Bulletin No. 171, the Corps of Engineers concurs in general with the conclusions of DWR contained therein and with the proposed foreword.

Your cooperation in permitting the Corps to participate in the review of this bulletin in the interest of continued State-Federal interagency cooperation is appreciated.

Sincerely yours,

John A. B. Dillard

JOHN A. B. DILLARD
Brigadier General, U. S. Army
Division Engineer

CHAPTER 4. INVESTIGATIVE ACTIVITIES

Various activities necessary to provide the data needed for the route comparisons are reported in this chapter. These activities include investigations to define the water supply for the project, its operation, water yield, cost of physical features and benefits. Generalized conclusions regarding reservoir storage requirements and yield are also drawn.

Project Hydrology and Operation

This section presents information on water supply hydrology, reservoir operation studies, filling time, local water demands, and water releases required for fisheries preservation. Detailed data and discussions on project hydrology and operations are contained in the hydrology office report made to support this bulletin.

Runoff

The greatest annual rainfall and surface runoff in California occurs in the North Coastal area, which includes the Eel River Basin. The amount of precipitation and runoff increases generally from south to north and from east to west. The climate is distinctly seasonal, with cold, wet winters and warm, dry summers.

Figure 12 shows the runoff pattern for the Middle Fork Eel River at the Dos Rios damsite. This figure indicates the seasonal characteristics of the runoff; over 80 percent of the runoff occurs during the five-month period from December through April inclusive. In addition to these seasonal characteristics, rainfall and subsequent runoff are quite variable from year to year, as shown in Figure 13.

The estimated minimum annual flow at Dos Rios damsite is approximately 200,000 acre-feet, and the maximum is nearly 2,500,000 acre-feet, with an average annual inflow of just over 1,000,000 acre-feet. Comparable statistics for the other major reservoirs considered in the route comparisons are given in Table 5.

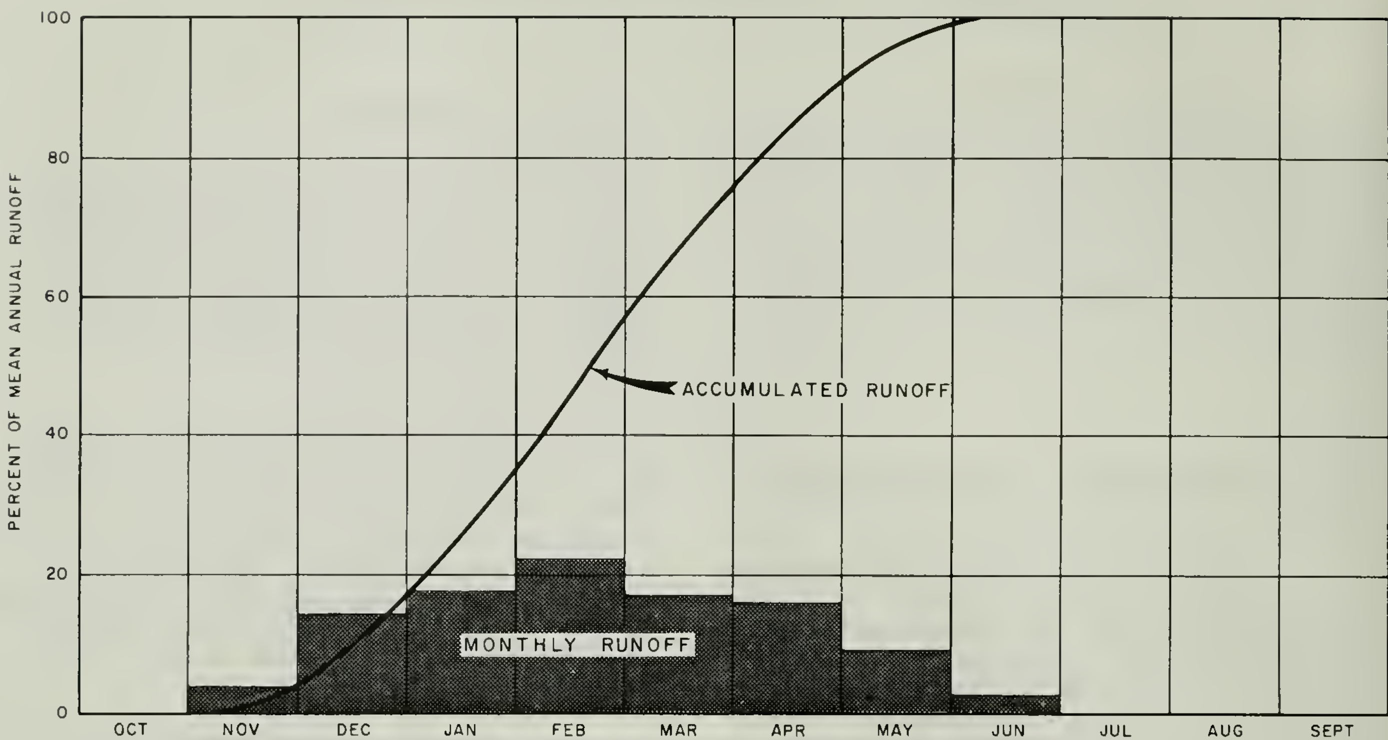
Period of Recorded Data

The reservoir inflow data used in the operations studies to determine project water yield were developed from stream gaging stations in the area. Stations with short periods of record were extended through correlations with long term stations so that runoff estimates for all stations covered the study period 1911-1960.

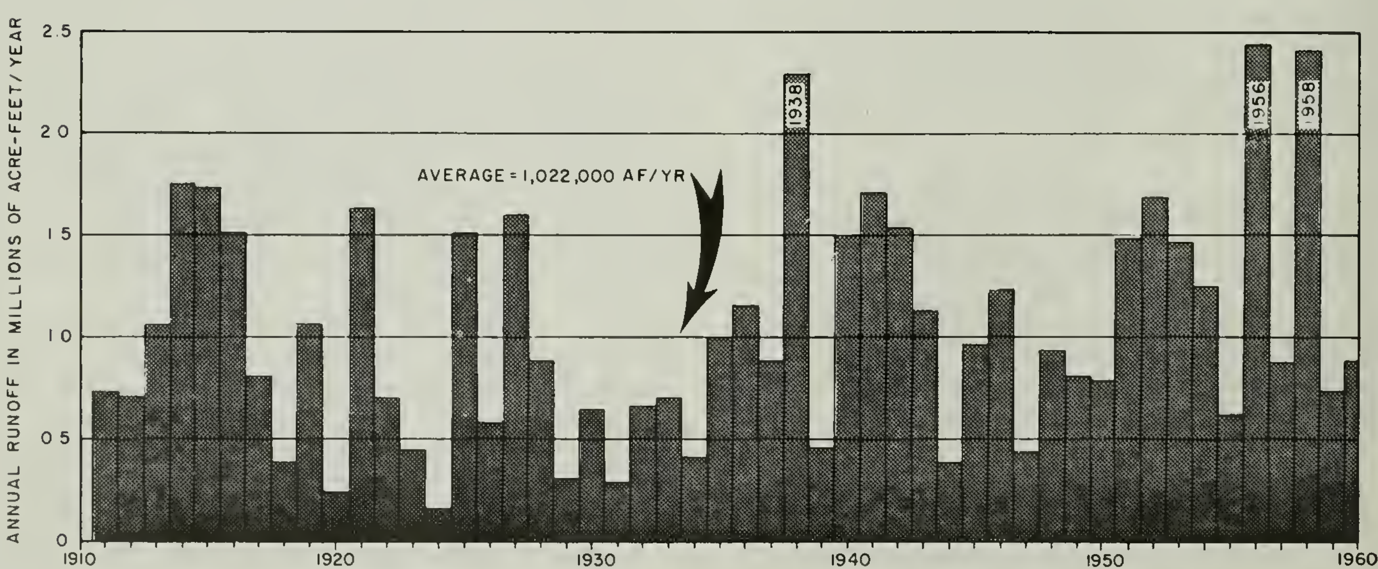
The Eel River Basin stream gages were correlated with the gages at Van Arsdale and at Scotia for which records are available for all but one year of the study period. The Van Arsdale and Scotia records were corrected for the effects of Lake Pillsbury operation and diversions through the Potter Valley powerhouse. Damsite inflow values were obtained from gaging stations records by area-precipitation relationships.

For the three reservoirs comprising the Glenn Complex along the west side foothills in the Sacramento Valley, the runoff of Thomes Creek at Paskenta, where 45 years of records exist, was estimated for the remaining portion of the 1911-1960 study period by correlation with flows in the Sacramento River at Red Bluff. The runoff of North Fork Stony Creek at Newville damsite constitutes the local inflow into Newville Reservoir. This was computed for the study period by the Bureau of Reclamation by adjusting the North Fork Stony Creek gage record and by an area-precipitation correlation with the neighboring Thomes Creek at Paskenta runoff. For Rancheria Reservoir, the inflow was determined by adjustment of the record at the Stony Creek gages at Fruto, Orland and Black Butte, and by correlation with flows in the Sacramento River at Red Bluff.

For the three alternative damsites on Cache Creek, the runoff was estimated as follows. The runoff at the Wilson Valley damsite was estimated by correlation with existing stream gages on Cache Creek and North Fork Cache Creek near Lower Lake, using an area-precipitation relationship. The stream gage records had previously been corrected to account for the operation of Clear Lake by the Clear Lake Water Company. The runoff of Cache Creek at the two remaining damsites, Kennedy Flats and Blue Ridge, was assumed to be the same as that at Wilson Valley damsite.



MONTHLY DISTRIBUTION OF MEAN ANNUAL RUNOFF
M.F. EEL RIVER AT DOS RIOS DAMSITE
FIGURE 12



ANNUAL INFLOWS TO DOS RIOS RESERVOIR
FIGURE 13

Clear Lake inflow records were computed from Clear Lake Water Company release records and precipitation and evaporation records. These records then became the basis for the various operations studies.

Details of the hydrologic estimates for each of the reservoirs investigated are computed in the "Hydrology" office report.

TABLE 5

INFLOW DATA FOR MAJOR PROJECT RESERVOIRS FOR THE STUDY PERIOD 1911-1960
(All values in thousands of acre-feet)

Reservoir	Minimum Inflow 1/ Monthly	Minimum Inflow 1/ Annual 2/	Maximum Inflow 1/ Monthly	Maximum Inflow 1/ Annual 2/	Average Annual Inflow
Dos Rios	0.3 Aug. 1920	160.0 1923-24	889.4 Dec. 1955	2433.0 1955-56	1022.3
Paskenta	0.0 26 Months	32.5 1923-24	163.7 Feb. 1958	456.4 1957-58	192.5
Newville	0.0 155 Months	8.1 1923-24	20.3 Feb. 1958	63.1 1915-16	27.0
Rancheria	0.0 Aug. 1912	28.4 1923-24	384.1 Feb. 1958	1045.0 1957-58	338.0
English Ridge	0.1 Oct. 1955	65.7 1923-24	600.4 Jan. 1914	1514.0 1937-38	653.8
Clear Lake	0.0 Aug. 1926	118.5 1920-21	386.2 Jan. 1914	1029.2 1957-58	437.3
Wilson Valley	0.0 44 Months	18.5 1930-31	211.5 Feb. 1958	516.0 1957-58	155.4

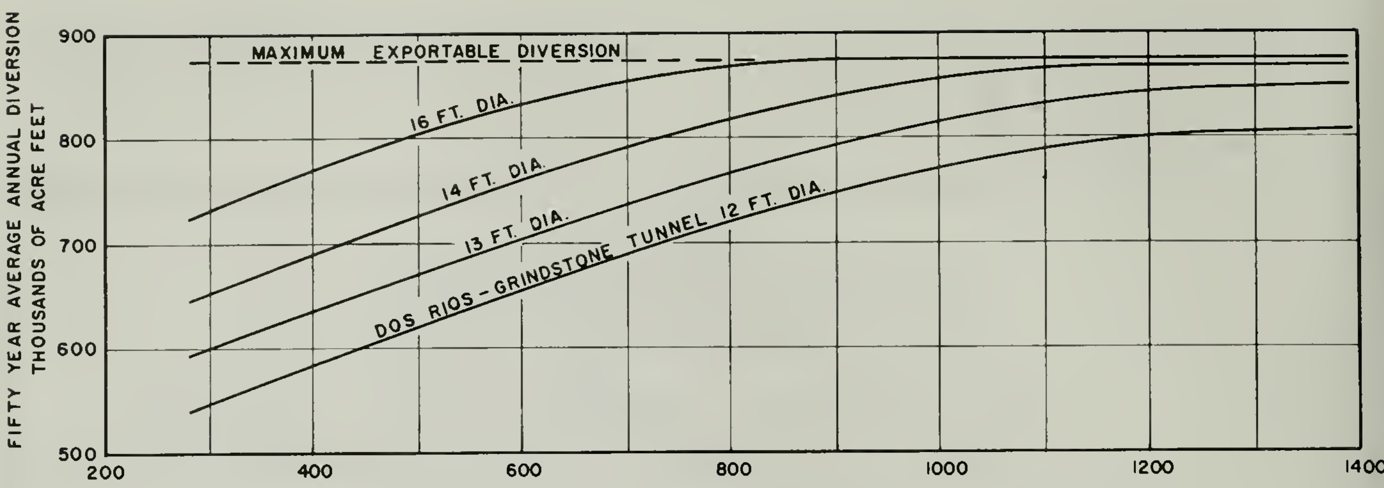
1/ Amount of flow and dates of occurrence shown.
2/ Date shown is water year, beginning October 1 and ending September 30.

Reservoir Storage Requirements

A large reservoir on the Middle Fork Eel River is necessary to control the extremely variable runoff by providing adequate space for long-term carryover storage and for annual reregulation, so that flows may be diverted to the Sacramento Valley on a reasonably uniform monthly and annual basis. With insufficient storage space on the Middle Fork, the size of the tunnels or pumping plants to divert the large winter flows must be greatly increased. This is illustrated in Figure 14, which shows the average annual diversion possible over the 50-year study period for various sizes of conveyance systems and reservoir active storages. The graph shows that to divert large amounts of water while restraining the size of the reservoir would require a larger diameter of tunnel.

Increasing the size of the conveyance features in order to avoid construction of a large reservoir has been shown in the studies to be economically unjustified. It would be less expensive to provide the necessary storage than to provide a large conveyance system which would only be used to capacity four or five months out of the year.

To illustrate in another way the necessity of a large storage reservoir on the Middle Fork Eel River, the diversion capabilities of three possible sizes of Dos Rios Reservoir are compared for a wet year, 1952, in Figures 15, 16, and 17. Figures 15 and 16 illustrate operation of a 536,000 acre-foot reservoir; Figure 15 shows the diversion capability with a conveyance system capacity of 100,000 acre-feet per month and Figure 16 shows the diversion capability with a conveyance system capacity of 150,000 acre-feet per month.



DIVERSION CAPABILITY - DOS RIOS-GRINDSTONE TUNNEL
FIGURE 14

Figure 17 illustrates the operation of a 3,000,000 acre-foot reservoir with a conveyance system capacity of 100,000 acre-feet per month.

Comparison of the three examples in Figures 15, 16, and 17 indicates the following:

1. The relatively small volume of water diverted and the large amount of spill with the plan shown in Figure 15 is due to the combination of small active storage capacity and small conveyance capacity which results in minimal and sporadic operation of the export conveyance works. Such a system would be highly inefficient and would not fully develop the river.

2. The amount of water diverted may be increased as shown in Figure 16 by increasing the size of the conveyance works. This would reduce spills, but the larger conveyance works would be more costly and would still operate inefficiently.

3. As shown on Figure 17 it would be possible by increasing the reregulatory storage space in Dos Rios Reservoir to increase the amount of water diverted and reduce the spill to zero. The size and cost of the conveyance works would be reduced because the water would be diverted on a uniform 12-month schedule, thus allowing more efficient use of the tunnel.

4. The examples shown in Figures 15 and 16 start and end with the reservoir drawn down to minimum storage while the example in Figure 17 starts with near-minimum storage but ends with an additional 587,000 acre-feet of water for use during future dry years. At the same time it provides about the same amount of water as the example in Figure 16. This illustrates that a small Dos Rios Reservoir is highly inefficient during wet years, and would contribute very little to project yield during dry years, when the actual divertable inflow is small. A large Dos Rios Reservoir, on the other hand, would increase yields in both wet and dry years.

Project Water Yield

It was assumed in this comparison of alternative routes that the Upper Eel River Development would supply the next increment of water to the existing and authorized State Water Project and Central Valley Project system. In actuality, there are several potential projects which could provide for a portion of the needs during this same time period; they include the Paskenta-Newville and Marysville Projects. While the actual position of a particular project in the sequence of construction of future projects will have an effect on the conservation yield attributable to that project and on the manner in which it will be integrated operationally into the system, the assumption concerning the staging of the Upper Eel River Development does not affect the comparison of alternative routes. The actual staging of Upper Eel River Development will be determined during subsequent studies.

The average amount of export yield which can be developed by the Upper Eel River project is limited to the average runoff of the various streams, such as the Eel River, Thomes Creek, Stony Creek, and Cache Creek, which is surplus to the needs of the areas of origin. By providing large reservoir storage,

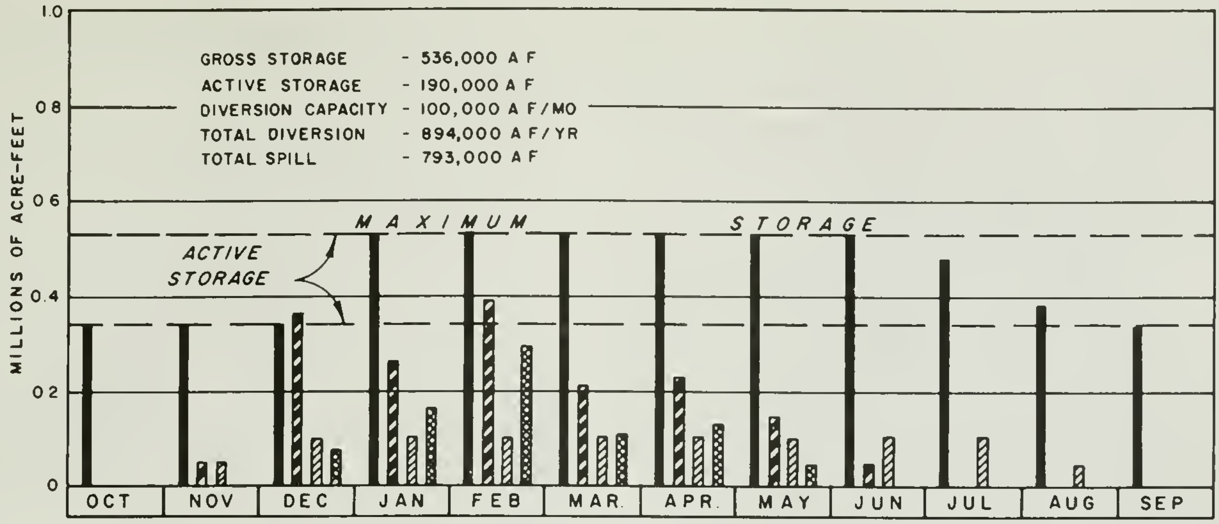
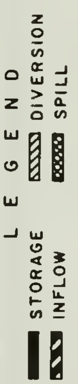


FIGURE 15: OPERATION OF SMALL DOS RIOS RESERVOIR FOR WATER YEAR 1952-53



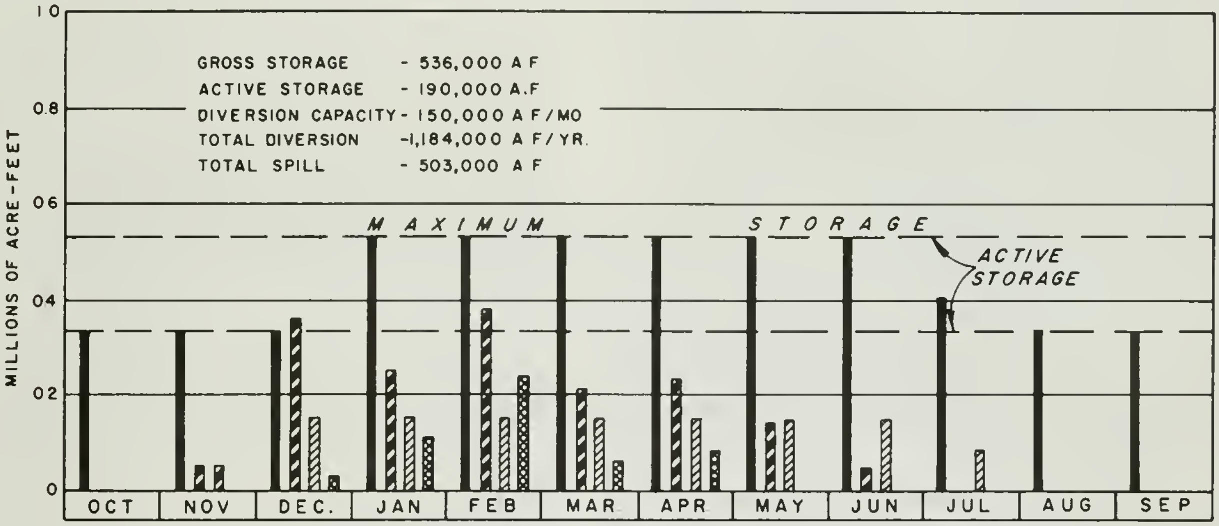


FIGURE 16: OPERATION OF SMALL DOS RIOS RESERVOIR FOR WATER YEAR 1952-53

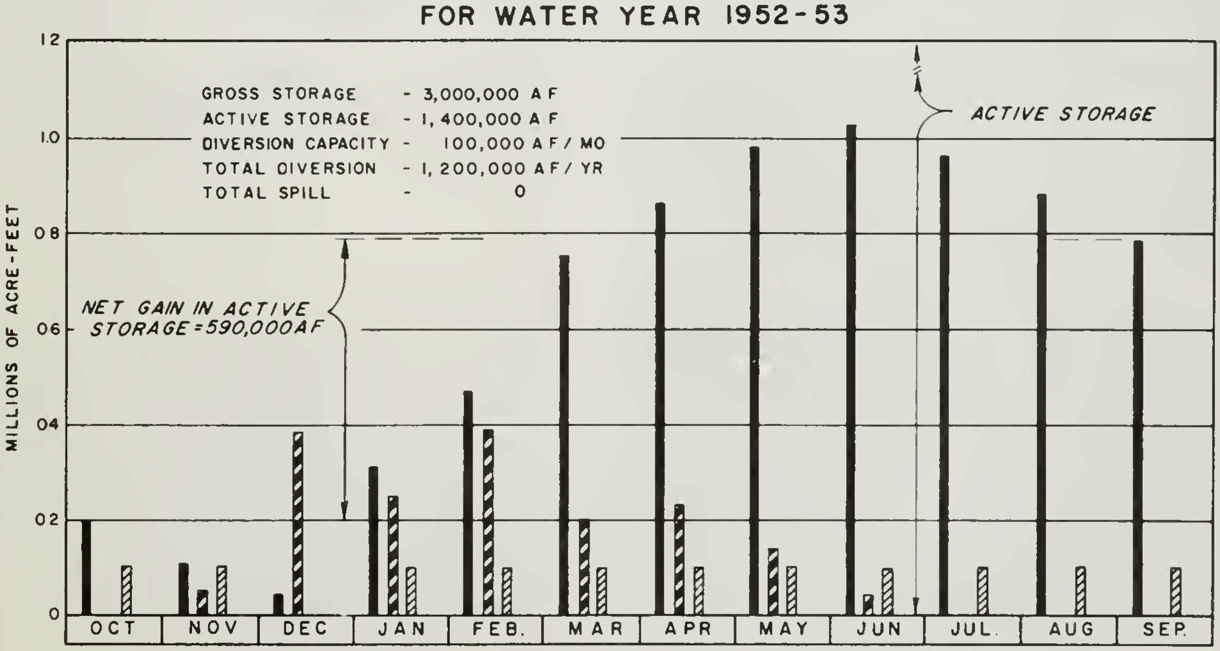


FIGURE 17: OPERATION OF LARGE DOS RIOS RESERVOIR FOR WATER YEAR 1952-53

the large winter runoff can be stored for later release. During critically dry years, large releases would be made from storage when needs are the greatest. During average to wet years when less augmentation of flows in the Delta would be required, less water would be released from storage.

This has been the underlying principle of the operations studies--to release on a historical basis only as much water as will insure that the storage reservoirs will be full at the start of the historical critically dry period, 1928 through 1934. The long-term yield of the project was determined for each combination of alternatives as the largest release which could be made and still leave the storage space full at the start of the historical dry period. During this period, the reservoirs' full active storage capacity would be released over the 7-year period, along with the annual inflows. The total yield of the project during the 7-year period, then, is the sum of the releases from inflow and from storage. These releases will enable the State Water Project to meet its commitments. By providing enough storage, the commitments of the present State Water Project can be met largely from storage drawdown during the dry years, and additional water can be provided on a firm basis for supplemental contractors to an expanded State Water Project and/or Central Valley Project. A discussion of the present "closed" system and of an expanded "open" system is presented in Chapter 3 under "Future Water Demands".

The actual operations studies used to estimate yields for the many alternative projects studied for route selection were performed by a digital computer. Yields were determined for various combinations of features on both routes. Table 6 illustrates the results of the studies performed in this manner. Within each square the average annual yield during the critical period of 1928-34 is shown first, and the average annual yield for the remaining 43 years of the historical 1911-60 study period is shown next.

On the Clear Lake Route, the English Ridge Project was integrated into the operations studies and its estimated annual yield of 212,000 acre-feet per year is included in the tabular values. By comparison with the requirements for local water shown in the section on benefits, it can be seen that the English Ridge project would be capable of satisfying ultimate demands in the Clear Lake --Cache Creek and upper Putah Creek areas, with supplemental water also available to Solano County and the Delta.

As a result of the operations studies a number of generalized conclusions were drawn. These are:

1. The minimum active storage required on the Middle Fork Eel River to control the runoff is 1,000,000 to 1,500,000 acre-feet.

2. With a low-level Dos Rios Reservoir having a capacity of 536,000 acre-feet, the maximum amount of water which could be diverted from the Middle Fork Eel River during the 1928-34 critically dry period is 357,000 acre-feet per year, or 35 percent of the 50-year average annual runoff. With an 8,000,000 acre-foot Dos Rios Reservoir, the critical period diversion to the Sacramento Valley would be 1,200,000 acre-feet per year, or 120 percent of the 50-year average.

3. With a minimum Middle Fork Development of 536,000 acre-feet, 3,000,000 to 4,000,000 acre-feet of active storage is necessary on the Sacramento Valley side to reregulate Middle Fork Eel River diversions to a schedule compatible with needs in the Delta. By providing over 3,000,000 acre-feet of storage space on the Middle Fork, the amount of active storage necessary for reregulation on the Sacramento Valley side could be reduced to about 1,000,000 to 1,500,000 acre-feet.

4. It would be possible to meet the needs of the present State Water Project by a combination of a small 536,000 acre-foot Dos Rios Reservoir, a large tunnel, and approximately 5,000,000 acre-feet of storage in the Glenn Complex. It would also be possible to meet present system needs with a combination of a 7,000,000 acre-foot Dos Rios Reservoir and a large tunnel.

5. The reservoirs of the Clear Lake Route would be extremely difficult to operate in an efficient manner with a minimum of waste of water and power.

Filling Time

A critical factor in the timing of construction of the Upper Eel River Development will be the time required to fill the large storage reservoirs to full operational capability. Preliminary filling time studies indicate that, to fill the larger sizes of reservoirs considered on the Glenn Route, about 12 years should be allowed. The full operational capability of this larger scale of development would not be required until about 1996. Thus filling would have to com-

TABLE 6

ALTERNATIVE PROJECTS ANALYZED FOR ROUTE SELECTION

Middle Fork Feature 3/	CACHE CREEK FEATURE				GLENN COMPLEX FEATURE							
	W.V. 1.00	K.F. 2.25	B.R. 3.00	B.R. 4.00	P-N-R 5.00	P-N-R 6.00	P-N-R 7.00	P-N-R 8.00	RANCHERIA 2.50	RANCHERIA 4.00	RANCHERIA 5.06	P-N 2.86
.536 MAF Dos Rios	612 1/ 702 2/	797 762	902 827	1040 817	865 772	998 763	1132 752	1269 743	584 663	825 636	990 627	622 705
.536 MAF Dos Rios+ Small Spencer	652 937	856 958	961 937	1110 920	876 854	1010 845	1142 834	1278 825	657 738	868 719	1000 709	693 794
.536 MAF Dos Rios+ Large Spencer	683 910	901 925	1006 935	1152 912	910 852	1043 843	1176 832	1312 823	706 743	902 717	1045 707	734 797
3.00 MAF Dos Rios w/o Round Valley	867 821	1062 812	1182 849	1312 812	1124 826	1260 817	1395 806	1533 797	869 725	1072 700	1204 681	880 779
3.00 MAF Dos Rios with Round Valley	785 877	926 828	1040 787	1186 894	1010 829	1145 820	1279 809	1417 800	754 728	957 703	1089 684	773 783
4.50 MAF Dos Rios with Round Valley	923 821	1112 812	1252 801	1387 746	1218 820	1352 811	1487 800	1625 791	950 717	1150 696	1283 675	982 770
6.00 MAF Dos Rios with Round Valley	1155 815	1358 773	1457 773	1597 773	1426 809	1560 800	1695 789	1833 780	1158 706	1358 685	1491 664	1190 757
8.00 MAF Dos Rios with Round Valley	1449 783	1619 766	1721 737	1896 737	1705 799	1839 790	1974 779	2112 770	1431 696	1634 675	1768 654	1462 740

Abbreviations:
W.V. - Wilson Valley Reservoir
K.F. - Kennedy Flats
B.R. - Blue Ridge
P. - Paskenta
N. - Newville
R. - Rancheria

Notes:
1/ Top number=7-year total yield, thousands of acre-feet/year
2/ Bottom number=43-year total yield, thousands of acre-feet/year
3/ Reservoir capacities in millions of acre-feet (MAF)

mence in 1984; allowing time for construction of the dams and tunnel, tunnel construction may well have to commence in 1974, with the dam being started a few years later, depending on the possibilities for staging.

For the smaller scales of development, the filling time would be proportionately less, but the date at which full operational capability must be met would advance to about 1990 for the smaller projects considered. The net effect would be very slight on the starting date for the tunnel and reservoir, amounting to a year or two later start.

The studies of filling time for the Clear Lake Route indicated that the size of pumping plant from Dos Rios Reservoir and the size of the Cache Creek Reservoir would be most influential in determining filling times. In general, filling times would be similar, but slightly longer than for the Glenn Route.

The reservoir filling problem, which is critical in construction timing, will be more completely studied in Phase II of the Advance Planning Program.

Local Demands for Water

One of the objectives of the Advance Planning Program was to identify local water needs which could be served from the Upper Eel River Development and to define the appurtenant works necessary to supply these needs. In cooperation with the Bureau of Reclamation, local service areas were identified and water requirements estimated. Monthly schedules of required releases were established and then provision for local needs was integrated into the operations studies.

Inasmuch as it is envisioned that the Upper Eel River Development would be a joint state-federal undertaking it was assumed that the Bureau of Reclamation would provide water for all of the local agricultural service areas. Figure 1 shows the various local service areas in relation to project features.

Reservoir Releases for Fisheries Preservation

The California Department of Fish and Game, through its contract services with the Department of Water Resources, has provided preliminary estimates of the amount of water which must be released from Dos Rios and English Ridge Reservoirs to preserve important anadromous fisheries in the Eel River. Dos Rios Dam would block average runs of 13,000 king salmon and 23,000 steelhead from their ancestral spawning grounds. This loss of spawning area would be mitigated by construction and operation of a fish hatchery below Dos Rios Dam with a capacity of 65,000,000 eggs. The annual water release to supply the hatchery, assure fish passage to and from the hatchery, and preserve the fish spawning below the hatchery is estimated to be 124,000 acre-feet. This is approximately 12 percent of the average annual flow past Dos Rios damsite.

English Ridge Dam would block approximately 10,000 king salmon and 14,000 steelhead from their spawning grounds. To mitigate this loss of spawning area, a fish hatchery with a capacity of 50,000,000 eggs is planned below English Ridge Dam. The estimated annual water release to supply the hatchery, assure fish passage and preserve spawning below the hatchery would be 112,000 acre-feet. This would be approximately 22 percent of the average annual runoff past English Ridge damsite as impaired by the present Potter Valley powerhouse releases.

Costs and Benefits

The following sections present details concerning the procedures used to design the various physical features, such as dams, tunnels, and pumping plants, and to estimate their cost. Summaries of the benefits used in the comparison of the alternative projects and routes are also presented.

Costs

The estimates of costs used in the route comparisons were prepared by the Department, with the exception of English Ridge Dam and Reservoir, which was prepared by the Bureau of Reclamation. The cost estimating procedures varied, depending upon the significance of the particular feature and also upon the amount of time and money available for collection of the basic data for estimating.

Dam and reservoir costs were estimated generally in the greatest detail, because of their relatively large effect on the total cost. Tunnel costs were also estimated in as much detail as possible, commensurate with the exploration which could be accomplished. Pumping plant and appurtenant costs were estimated in less detail, because of their generally lower cost and significance. Allowances were made in all cost estimates for costs of engineering, administration, contingencies and interest during construction.

The following sections describe the procedures followed in making the designs and cost estimates for each kind of structure. The general procedure described for studies of land acquisition costs was used with estimates for all structures.

Land Acquisition. As part of the Advance Planning Program for the Upper Eel River Development, a study was made to determine the costs of lands and improvements which would be acquired by the project. Estimates were made of the maximum amount of land which would be required for the various reservoirs and other features; ownerships within these areas were then delineated and an inventory taken of all improvements. The estimated value of these lands and improvements was determined by checking recent sales of comparable property in the area. Estimates were also made of the cost which would be required to relocate roads and utilities within the project area.

One aspect of the study was to determine the rate of escalation in property values over the past five-year period. The results showed that property values in the project areas had escalated somewhere between seven and ten percent per year over this period. It is likely that this escalation will continue, probably at a more rapid rate due to population expansion and other factors.

The property cost estimates made for route selection are contained in a two-volume office report prepared by the Department's Division of Right-of-Way Acquisition. A supplementary study was made to determine the market value of land and improvements in Round Valley which would be required as part of a large Dos Rios Reservoir development. Consideration in this latter study was also given to the problem of acquiring Indian lands in the Round Valley area.

Dams and Reservoirs. In preparing the cost estimate for a dam and reservoir, previous studies on the site were reviewed for pertinent information, and basic data on the following aspects was acquired.

Mapping -- Layouts of dams were made on the best available topographic maps. These were usually at least 1" = 400' with a contour interval of 20 feet.

Foundation geology -- The exploration work done at the damsite was reviewed and special features and problems were noted. The dam design was based on a conservative interpretation of the foundation conditions revealed by the exploration.

Construction Materials -- The availability of materials of sufficient quality and quantity to construct a dam of the required size greatly influenced the cost estimate. Special care was taken in this regard to be as realistic as possible.

Hydrology -- Data on flood hydrology was reviewed and updated as required, and designs of the diversion works, outlet works, and spillway were based on these estimates.

Area-Capacity Data -- The area of each reservoir was planimetered and curves showing the increase in reservoir surface area and capacity with elevation were used in the estimating procedure.

The design of the dam itself was based on a conservative interpretation of the existing conditions as far as they were known. Detailed designs were prepared for most dams, but where sites and construction materials appeared to be similar, a modification of an existing detailed design was used. The various aspects of the design were handled as follows:

Axis Selection -- The axis was selected, in general, so as to present the optimum combination of embankment volume and foundation competence. In some cases, minimum embankment volume was the only criterion which could be used.

Materials Selection -- The available sites for construction materials were located, and unit costs for excavating, processing, hauling, and placing the material were calculated by estimating the required equipment and labor to accomplish the task.

Dam Design -- The actual design was based on use of the available material, with stability analyses performed according to Department criteria.

Foundation Treatment -- One of the more important aspects of the design and cost estimate, the required amount of stripping of unsuitable material under the dam, and subsequent foundation grouting requirements were estimated based on the geologic investigations of the site. Stripping estimates varied from less than 10 feet to more than 100 feet in places at several damsites.

Diversion During Construction -- The basic flood hydrology and estimated construction schedule were used to determine diversion capacity required. This was almost always provided by a tunnel through one of the abutments.

Outlet Works and Spillways -- In the interests of water quality control, multiple-level intakes were uniformly provided for at all reservoirs. Experience has shown that such provision would be eventually required in nearly all cases. Spillways were normally designed as gated overfall structures, with some exceptions. Concrete-lined chutes or tunnels were also provided, with energy dissipation devices to prevent downstream erosion in the vicinity of the toe of the dam.

The various work necessary to clear the reservoir area and relocate roads and other features was also estimated, on the basis of overall average unit costs derived for each reservoir. Relocation costs were based on map layouts and the application of typical unit costs per mile to roads, transmission lines, etc. In several cases, such as the large Dos Rios, Rancheria, and Greater Berryessa Reservoirs, special studies were made to better define the problems and costs.

Tunnels. The design of tunnels followed an abbreviated format similar to that for dams. Tunnel lengths, excavation volumes, and unit costs were estimated using the best geological interpretations available. Where limited or no subsurface exploration was available, conservative designs and cost estimates were prepared, notably at Garrett and Soda Creek Tunnels.

Pumping Plants. The only pumping plant under consideration was Elk Creek pumping plant. Its cost was estimated for both a low and a high Dos Rios Reservoir using estimates of probable unit costs and excavation volume. The pumping plant would be an underground installation with a high Dos Rios Reservoir. The large fluctuations in draft head on the pumps would cause unprecedented design problems, and for this reason, the estimate made was very preliminary based on the limited information available.

Conveyance Channels. The design of the various conveyance channels also followed closely that of the dams. The studies were made, however, in only enough detail to give minimum costs.

Office Reports on Designs and Cost Estimates. The various designs and cost estimates are bound in six volumes as office reports supporting this bulletin. These volumes are as follows.

Volume 1 - Paskenta, Newville, and Rancheria Reservoirs, Chrome Dike, and the Stony Creek Conveyance Channel.

Volume 2 - Etsel, Lower Etsel, Spencer, and Dos Rios Reservoirs, and Franciscan damsite on the Middle Fork Eel River.

Volume 3 - Spencer-Thomes, Spencer-Grindstone, Dos Rios--Grindstone, Elk Creek, and Garrett Tunnels.

Volume 4 - English Ridge Reservoir provided by the Bureau of Reclamation.

Volume 5 - Wilson Valley, Kennedy Flats, and Blue Ridge Reservoirs and the Cache Creek Conveyance Channel.

Volume 6 - Stienhart, Jerusalem, and Greater Berryessa Reservoirs, Soda Creek Tunnel, and the Putah Creek Conveyance Channel.

Benefits

This section discusses the criteria used to evaluate benefits for the various project functions. It also includes summaries of benefits for local water supply, recreation, and flood control.

Benefits are a standard for measuring the economic accomplishments of a project. In combination with the costs, they allow the planner to choose between alternative courses of action so as to follow the dictum of "achieving the most good for the least cost". This guiding principle was followed in this report in the comparisons of benefits, costs, net benefits and benefit-to-cost ratios in Chapter 2.

Export Water Supply. The estimates of the amount and timing of water to offset depletions to the present State Water Project were taken from material published in Bulletin No. 132-66 and 132-67, "The California State Water Project". This amount, called the "closed system" demand, is estimated to be 900,000 acre-feet per year by 2035 during critically dry periods. Practically speaking, it is the minimum Delta yield requirement for the project.

The basis for the buildup of water demands beyond that serviceable from the present State Water Project and Central Valley Project was data published in Bulletin No. 160-66. These continuing water requirements have been called "open system" requirements.

A unit value of $30 per acre-foot was assigned to water in the Delta to determine the benefits attributable to export water supply to the Delta. This value was derived from consideration of the cost of alternative sources of water in Southern California and the San Joaquin Valley and of the cost of transporting the water to areas of use. For this analysis the same unit value was assigned to all export water, whether it would be used by the present "closed" system or in an expanded "open" system.

Local Yield. It was assumed for purposes of the analyses presented in this report that the project would be a joint federal-state undertaking and that the Bureau of Reclamation would provide service for the local water demands. For this purpose, the Bureau is currently studying the English Ridge Project to provide for local needs around Clear Lake and upper Putah Creek, and the Paskenta-Newville Project to provide for local needs in the Thomes Creek--Newville area.

Estimates of local requirements for water were provided by the Bureau of Reclamation. They also provided estimates of unit benefits for the various areas. In accordance with Department policy, however, only the direct portion of these benefits was considered. In some cases, such as the lower Cache Creek area where Bureau of Reclamation data was not available, Department estimates were used.

Table 7 shows in summary the local water requirements and benefits used in this study.

TABLE 7

SUMMARY OF LOCAL WATER REQUIREMENTS AND IRRIGATION BENEFITS

Service Area	Average Annual Water Requirements in Acre-feet 2/	Present Worth of Net Benefit 3/
Thomes Creek 1/	37,500	$19,320,000
Round Valley	27,000	10,140,000
Clear Lake	50,000	32,860,000
Clear Lake, Municipal and Industrial	15,000	22,530,000
Upper Putah	45,000	21,120,000
Lower Cache	35,000	13,690,000
Solano 4/	35,000	24,970,000

1/ Includes Newville service area.
2/ At farm headgate. Estimated 2020 level of development.
3/ Interest at 4 percent for 100 years.
4/ Supplemental water supply to West Sacramento Canal and Solano Project (excluding Delta, Marsh Lands and Montezuma Hills).

Recreation. Enhancement of water-oriented recreation opportunities is an important part of the Upper Eel River Development. For each reservoir, the California Department of Parks and Recreation provided estimates of the potential recreation use around the reservoir and of the cost of the necessary onshore facilities. Monetary equivalent values of such recreation usage were derived through the recreation subgroup of the California State-Federal Interagency Group. The estimates of the unit value of the benefit due to one visitor-day of recreation use ranged from $0.90 to $1.20, depending on reservoir operational schedules, location and access, variety and quality of recreation experience, and aesthetic considerations. Further work by recreation planners will undoubtedly change estimates for individual reservoirs, but the overall level of the estimates was sufficient for route selection. Table 8 shows in summary form the total recreation benefit at the various reservoirs, as estimated for this report.

TABLE 8

SUMMARY OF NET RECREATION BENEFITS
ATTRIBUTABLE TO UPPER EEL RIVER DEVELOPMENT

Reservoir	Present Worth of Benefit 1/
Paskenta	$ 3,580,000
Newville	4,270,000
Rancheria	8,640,000
Small Dos Rios	4,720,000
Large Dos Rios	12,120,000
Etsel-Spencer-Franciscan	5,380,000
English Ridge	28,010,000
Wilson Valley, Kennedy Flats, or Blue Ridge	18,260,000
Stienhart-Jerusalem	3,470,000
Clear Lake	No Change
Lake Berryessa	No Change

1/ Interest at 4 percent for 100 years.

Flood Control. The Corps of Engineers is the federal agency with the primary responsibility for flood control. This organization provided estimates of the requirements for storage of flood flows and the associated benefits for each major reservoir. The values so provided are preliminary in nature, and changes may be expected as the number of reservoirs considered is narrowed and plans are more intensely studied.

In general, flood control benefits amount to less than 5 percent of the total benefits. They were not a significant factor in the route comparisons. Table 9 presents a summary of annual flood control benefits used in this study.

TABLE 9

SUMMARY OF NET FLOOD CONTROL BENEFITS

Reservoir	Present Worth of Flood Control Benefits 1/
Low Dos Rios	
without English Ridge	$ 4,900,000
including English Ridge	7,960,000
High Dos Rios	
without English Ridge	14,700,000
including English Ridge	18,380,000
Paskenta-Newville	14,950,000
Indian Valley	2,330,000
Wilson Valley or Alternate 2/	4,900,000
Transfer Clear Lake storage to Wilson Valley 3/	19,600,000
Wilson Valley or Alternate-sediment and debris storage	1,470,000

1/ Interest at 4% for 100 years.
2/ Assumes Indian Valley Reservoir not previously constructed.
3/ Requires modifications of existing court decrees on operations of Clear Lake.

CHAPTER 5. PHYSICAL FEATURES OF THE ALTERNATIVE ROUTES

This chapter describes the dams, reservoirs, tunnels, and other features which would be included in the alternative conveyance routes.

Middle Fork Eel River

Dos Rios Dam and Reservoir

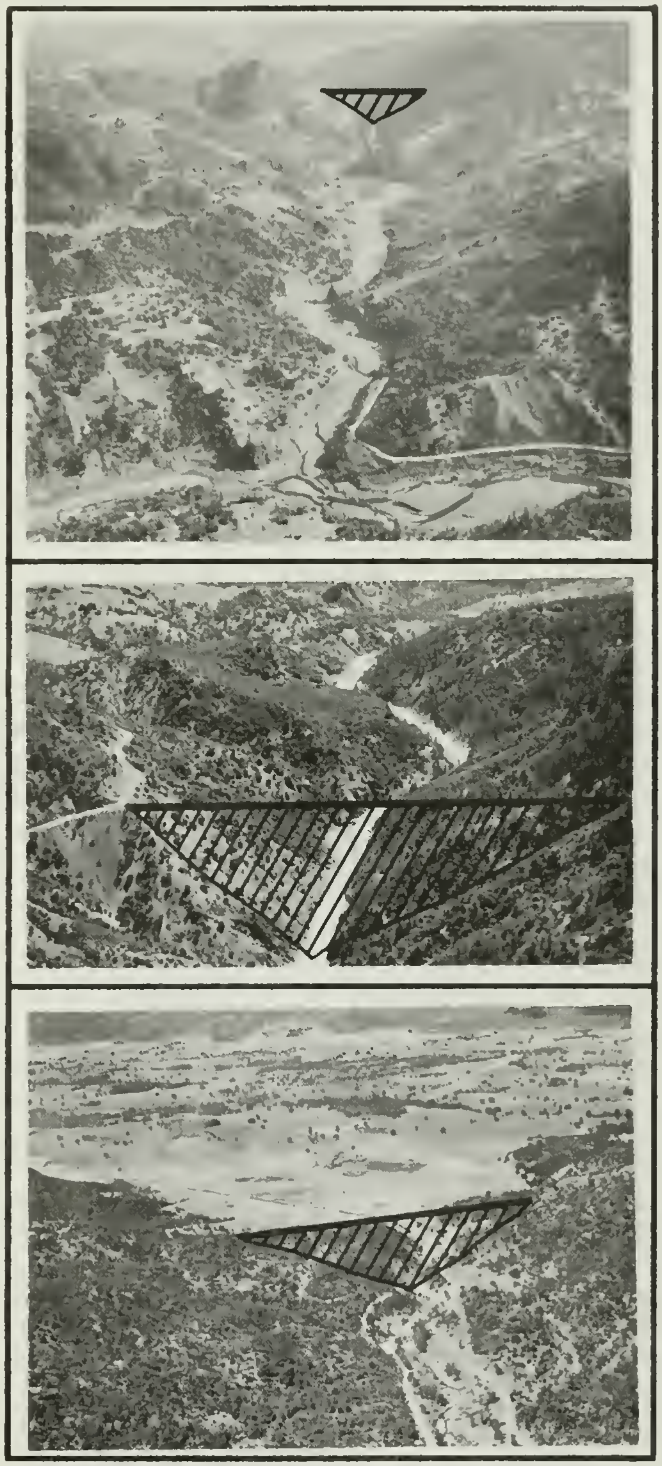
Surplus flows of the Middle Fork Eel River would be conserved behind Dos Rios Dam which would be located 2.5 miles upstream from the town of Dos Rios in Mendocino County. Based on surface exploration by the Department and subsurface drilling by the Corps of Engineers, it has been concluded that foundation conditions at the Dos Rios damsite are excellent and that the site is suitable for a high dam. The site is the best on the Middle Fork Eel River and one of the best in the North Coast.

Dams may be constructed for two alternative scales of development on the Middle Fork Eel River: one would require a high Dos Rios Dam, the other a low Dos Rios Dam. The reservoir impounded behind the high Dos Rios Dam would inundate Round Valley taking advantage of its vast storage possibilities; the low reservoir would not inundate the valley. The high dam, with a streambed elevation of 916 feet, would be of rockfill construction measuring up to 705 feet high with a crest length of nearly one-half mile. Statistics of the large Dos Rios Reservoir at a normal pool elevation of 1610 feet include a capacity of 8,000,000 acre-feet, a surface area of 41,000 acres (approximately the same as Clear Lake), and a shoreline of over 200 miles.

The small Dos Rios Dam would be of rockfill construction, 415 feet high, with a normal water surface elevation of 1320 feet. The reservoir formed by the smaller dam would have a capacity of 536,000 acre-feet, with a water surface area of 4,340 acres.

Dos Rios Dam and Reservoir would be operated as a multiple-purpose project giving full consideration to fish preservation, flood control, recreation, and export of surplus flows.

Dos Rios Dam would form an impassable barrier to migrating fish and inundate spawning areas. The estimated average annual run



Dos Rios damsite with junction of Middle Fork and main Eel River/closeup of Dos Rios damsite/ view of Round Valley from northeast -- Franciscan damsite in foreground.

consists of 13,000 king salmon and 23,000 steelhead. To preserve the Middle Fork Eel River anadromous fish runs, a hatchery with a capability of handling 65,000,000 eggs would be constructed below the dam and streamflow releases would be made. The hatchery would be located on the right bank of the river about ¼-mile downstream from the dam axis. Water would be supplied to the hatchery by means of a 110 cubic-feet-per-second-capacity pipeline originating at the reservoir.

To insure proper water quality and temperatures for the migrating salmon and steelhead, a multiple-level intake tower for the outlet works would be constructed on the left abutment near the dam. The intake tower would be connected to one of the two diversion tunnels used during construction.

Dos Rios Reservoir would offer good cold and warmwater fishing. Trout, bass, catfish, and bluegill would be the most important species.

By using surcharge storage above the normal pool elevation, a large Dos Rios Reservoir would provide complete flood control on the Middle Fork Eel River and a substantial degree of flood control in the Eel River canyon and delta. With this large reservoir, a glory-hole spillway could be used. The spillway would be located on the right side of the reservoir near the dam and would use one of the diversion tunnels as part of the spillway facilities.

A large Dos Rios Reservoir would offer varied recreation possibilities, such as boating, fishing, picnicking, swimming, camping, and boat-in camping. In order to develop its potential, many onshore recreation facilities would be constructed. The major emphasis would be placed on campground sites equipped with running water, flush toilets, and picnic tables in anticipation of a large amount of overnight use. Beaches, picnic areas, and paved boat ramps would also be provided at various locations around the reservoir. In order to gain access to the recreation areas, a network of paved two-lane roads would be constructed. The main recreation areas presently envisaged would be along the low rolling hills bounding Round Valley on the south and west.

To ensure the best possible recreation use of Dos Rios Reservoir, while still providing for the main function of water supply, storage would never be drawn down below elevation 1400 feet even in the driest of years. This elevation corresponds to a storage of 1,500,000 acre-feet and a water surface area of 20,000 acres.

Dos Rios--Grindstone Tunnel

Conserved water on the Middle Fork Eel River would be diverted by means of a gravity-flow tunnel to the Sacramento Valley for reregulation before final release to the Sacramento--San Joaquin Delta. During years of average or above-average runoff, a large Dos Rios Reservoir would release only minor quantities of water, thus essentially remaining full. During critically dry periods, such as occurred in 1928-1934, the storage of the reservoir could be released down to the minimum level of 1,500,000 acre-feet.

The Dos Rios--Grindstone Tunnel would have a west-to-east alignment; the inlet would be at elevation 1400 feet near the mouth of Hayshed Creek in the reservoir area and the outlet will be at an elevation of 1200 feet on Grindstone Creek. Having an inside diameter of 14 feet, the 21.2-mile-long tunnel would permit flows of over 2000 cubic feet per second to be diverted. Additional studies will be necessary to finally select the size and alignment of the tunnel.

Features of the 14-foot-diameter, concrete-lined tunnel include an intake structure, outlet works, emergency gate shaft, and construction shaft. The tunnel intake would be constructed in the main channel of the Middle Fork Eel River and would be connected to the tunnel by a reinforced concrete conduit. A multiple-level tunnel intake structure probably would not be required.

The flow would be controlled at the outlet portal in Grindstone Creek by means of an energy dissipation valve, thus making the tunnel a pressure conduit. The tunnel releases would discharge directly into Grindstone Creek.

An important feature of the tunnel would be an emergency gate shaft. The shaft, to be located near the west tunnel portal, would house a wheel gate. When closed, the gate would provide a means of dewatering the tunnel for emergency repairs or routine inspections.

The construction of the Dos Rios--Grindstone Tunnel will be a major undertaking. Not only does it have great length but it will be constructed through areas of complex geologic structure and under cover up to 5000 feet thick. In the past three years extensive studies have been made to determine the physical and economic feasibility of constructing such a tunnel.

Extensive surface exploration along the tunnel route has resulted in a general

West tunnel portal area within proposed Dos Rios Reservoir.

geologic map of the area. To get a better idea of what might be expected during construction, two deep holes have been drilled. Evaluation of the collected data has resulted in the conclusion that the Dos Rios--Grindstone Tunnel can be constructed but that it will be a technically difficult undertaking.

In October 1966, Dr. Frank Nickell, a world-renowned consulting engineering geologist, was retained by the Department of Water Resources to review the tunnel exploration program. Dr. Nickell's opinion is that the tunnel would be feasible. He stated that:

> "The breadth of geologic analysis by geologists of the Department of Water Resources and of others who collaborated is impressive. Confidence can be placed in the outline of conditions already available.
>
> "In my opinion, the proposed 14-foot diameter tunnel can be constructed in the Franciscan formation encountered along the indicated route with numerous problems to be sure, but as a practical venture."

In addition to reviewing the work done to date, he has made recommendations regarding further exploration, which will take place in Phase II of the Advance Planning Program.

Because of the extreme length of the Dos Rios--Grindstone Tunnel, the construction time will be very long. Emphasis will be given in the next stage of planning to location of construction shafts to reduce the overall construction time and cost. By building one or more construction shafts near the middle of the tunnel two more headings per shaft would be provided. One such shaft could be dug 1300 feet to tunnel grade beneath the Black Butte River near the center of the tunnel length. With four tunnel headings the construction time is expected to be 9 years.

Thomes and Stony Creeks

Upon entering Grindstone Creek, a tributary of Stony Creek, the Middle Fork Eel River diversions would flow into Rancheria Reservoir. Here the diversions would be reregulated before release to the Sacramento River.

Rancheria Dam and Reservoir

Rancheria Dam would be located on Stony Creek about 5 miles north of the town of Elk Creek in Glenn County and 15 miles upstream from Black Butte Dam. Constructed of Tehama formation soil, a gravelly-clayey sand, and stream gravel, the dam would rise 400 feet from its streambed elevation of 600 feet. The dam would have a total embankment volume of 62,000,000 cubic yards and a crest length of 6000 feet at a normal water surface elevation of 1000 feet.

A reconnaissance geology investigation concluded that the Rancheria damsite is suitable for a 400-foot-high fill-type dam. As a result of foundation drilling and materials testing conducted in the spring of 1967, the damsite has been found suitable for a height of dam even greater than that currently planned.

Located in a natural basin between the Coast Range foothills on the west and Rocky Ridge on the east, Rancheria Reservoir would form the southern compartment of the proposed Glenn Reservoir Complex. The town of Elk Creek and the existing Stony Gorge Reservoir would be inundated. Although the final size has not been determined, the reservoir, with a normal water surface elevation of 1000 feet, would have a capacity of 5,040,000 acre-feet, and a length of 19 miles. This corresponds to a surface area of 35,000 acres and 125 miles of shoreline.

Rancheria Reservoir would provide year-to-year reregulation of Middle Fork Eel River diversions along with long-term carryover storage. By controlling virtually all of the Stony Creek Basin, Rancheria Reservoir could assume the major portion of the responsibilities of flood control and irrigation now assigned to the existing East Park, Stony Gorge, and Black Butte Reservoirs.

Stony Gorge Dam and Reservoir within proposed Rancheria Reservoir area.

At the present time flood control for the lower Stony Creek area is provided by 150,000 acre-feet of storage in Black Butte Reservoir. A portion of this storage could be transferred to Rancheria Reservoir, thus necessitating less fluctuation of Black Butte Reservoir and thereby enhancing its recreation potential. In a similar manner it may be possible to maintain a more stable level at East Park Reservoir, thereby enhancing its recreation potential also. Due to the enhanced recreation attractiveness of Black Butte and East Park Reservoirs, Rancheria Reservoir may not initially attract substantial recreation use. For this reason initial installation of recreation facilities would probably be minimal. After a few years of project operation, the recreation demand should become apparent and facilities would be constructed accordingly.

The spillway at Rancheria Reservoir, consisting of an uncontrolled ogee weir and a variable-width concrete chute, would be located in a small saddle on the left abutment of Rancheria Dam. Flow from the chute would have its energy dissipated in a stilling basin about 1000 feet downstream from the toe of the dam.

In addition to export releases for the Sacramento--San Joaquin Delta, irrigation releases would also originate at Rancheria Reservoir. These would include the existing demands of the Orland Project for 108,400 acre-feet per year and also a proposed 57,000 acre-feet per year for lands between Black Butte Reservoir and the U. S. Bureau of Reclamation's proposed Sites Reservoir. Releases would be made through an outlet works equipped with a multiple-level intake for temperature and quality control. Located on the left abutment in the reservoir area, the intake structure would be connected to a 28-foot-diameter construction diversion tunnel.

Paskenta and Newville Dams and Reservoirs

The two northern units of the Glenn Reservoir Complex are called the Paskenta-Newville Project. Consisting of two reservoirs with a connecting spillway between them, they represent one of the most favorable remaining water conservation developments in the Sacramento Valley. While not dependent on diversions from the Middle Fork Eel River, the Paskenta-Newville Project would be enhanced by integration into the Upper Eel River Development. The Bureau of Reclamation is studying an independent project and also the possibility of delivering water from the lower Trinity River to the Paskenta-Newville Project. Additional studies will be required to determine the extent to which Middle Fork Eel River diversions should be brought into the project.

Paskenta Reservoir located on Thomes Creek in Tehama County would have a normal water surface elevation of 990 feet. At this elevation the reservoir would have a storage capacity of 105,000 acre-feet, a surface area of 1700 acres, and a shoreline of 15 miles. Newville Reservoir would straddle the Tehama-Glenn County line on the North Fork of Stony Creek. Statistics of Newville Reservoir would include a normal water surface elevation of 967 feet, a storage capacity of 2,860,000 acre-feet, a surface area of 16,300 acres, and 35 miles of shoreline.

Paskenta Reservoir would be operated to provide for local irrigation releases to Thomes Creek. The average annual runoff of Thomes Creek, amounting to 200,000 acre-feet, is so great in relation to the storage at Paskenta Reservoir that the reservoir would be at a high operating level most of the time. Spills from the reservoir would be diverted through a natural saddle at elevation 990 feet into Newville Reservoir. Newville Reservoir would be operated to make releases to the Sacramento--San Joaquin Delta and also to make small irrigation releases for service along North Fork Stony Creek. During average or wet years, there would be only minor releases to the Delta from the reservoir; during critically dry periods the entire storage of the reservoir could be released.

The Paskenta damsite is located two miles upstream from the town of Paskenta. To be constructed of zoned earth and rockfill, Paskenta Dam would have a height of 219 feet and crest length of 1400 feet.

The outlet works in Paskenta Dam would consist of a multiple-level intake tower, designed to draw water from different elevations, connected to a cut-and-cover conduit.

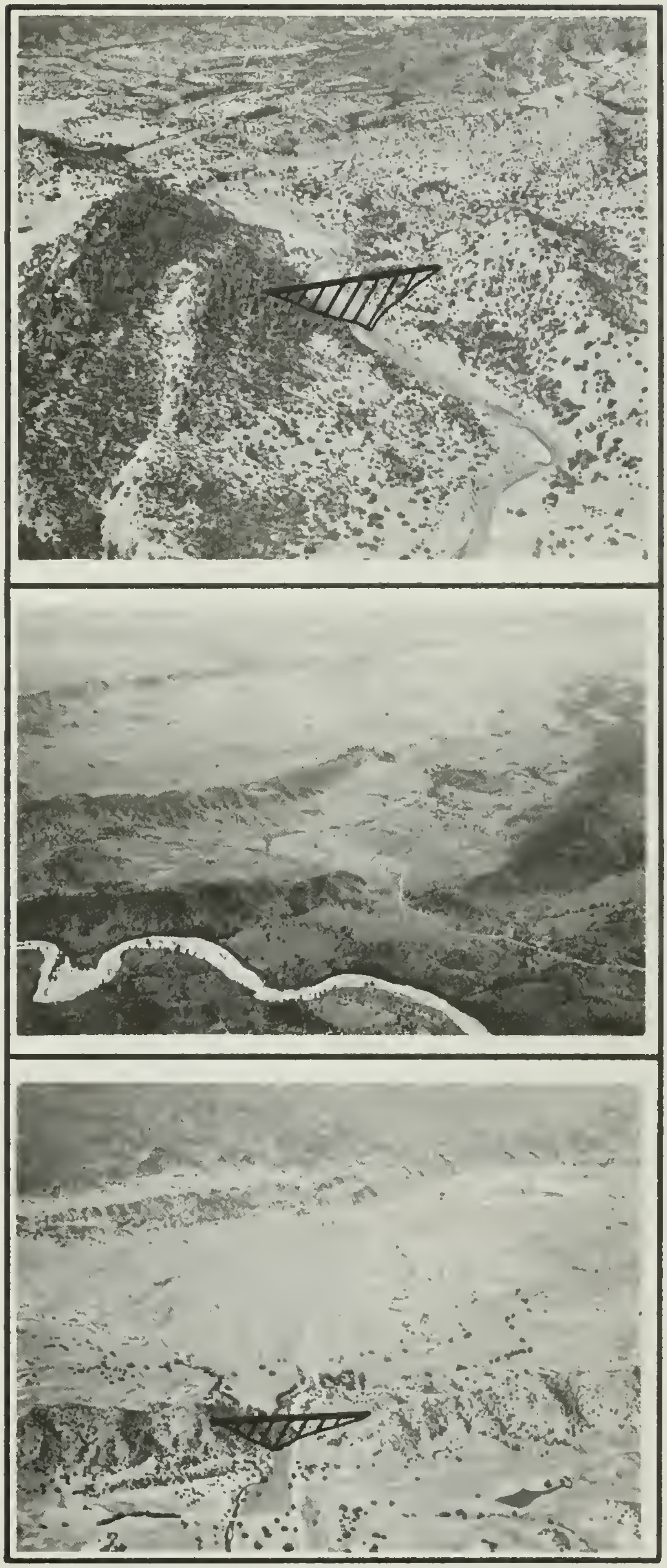
Newville Dam would be constructed of impervious clayey-gravelly soils, stream gravels, and rock. Located about 11 miles upstream from Black Butte Dam on North Fork Stony Creek, Newville Dam would be 386 feet high and would have a crest length of 4000 feet. In addition to the main dam, five small saddle dams will be required to prevent spillage over Rocky Ridge.

Spills from Newville Reservoir would be through a natural saddle on the north rim of the reservoir. The spills would enter Thomes Creek about one mile downstream from Paskenta Dam. With the large storage available, spills will occur very rarely if ever. Releases from Newville Reservoir would be made through an outlet works equipped with a multiple-level intake for temperature and quality control.

Recreation at the Paskenta-Newville Project would be centered mainly around Paskenta Reservoir even though it is much smaller. The constant high water level and attractive surrounding lands would make it a popular recreational area. In addition, a reservoir with moderate fluctuation generally offers better fishing than one with large fluctuations. Beaches, picnic areas, boat ramps, and excellent camping facilities would be provided. A network of paved roads would allow the recreationist to reach all facilities with ease.

Newville Reservoir, on the other hand, would have a fluctuating water surface and limited developable land. Minimum recreation facilities would be installed in response to demands.

As pointed out in the above description, Newville and Rancheria Reservoirs would have different normal water surface elevations. In order to prevent an uncontrolled interchange of water between basins, a dike would be constructed. With an east-west axis located one mile south of the settlement of Chrome, the dike would have a length of 4000 feet and a maximum height of 100 feet. A two-lane paved road would be constructed on the crest of the rock and soil structure and would serve as part of the road relocation network. By installing gated outlet works with the road bridged over it, controlled flow between the reservoirs would be possible.



Paskenta damsite and reservoir area/saddle for overflow from Paskenta Reservoir into Newville Reservoir area in background/Newville damsite and reservoir area.

Conveyance to Sacramento River

Releases from the Glenn Reservoir Complex to the Sacramento--San Joaquin Delta would travel through Black Butte Reservoir down Stony Creek and the Sacramento River to the Delta. It may be advantageous to construct a separate channel from Black Butte Dam to the Sacramento River. For route selection, the cost of a 15-mile long concrete-lined canal was included. The proposed alignment is shown in Figure 2 in Chapter 1.

Upper Eel River

English Ridge Reservoir

English Ridge damsite is located on the upper main Eel River in Mendocino County, approximately 11 air miles northeast of Willits and about 22 miles downstream from Lake Pillsbury. The reservoir which would be created would extend upstream to within a mile of the outlet of Lake Pillsbury. The Bureau of Reclamation has primary responsibility for planning on the English Ridge Project.

The proposed dam, of earthfill construction, would rise above the streambed approximately 550 feet to an elevation of 1733 feet. The crest of the dam would be approximately 2150 feet long. At the base along the streambed, it would be nearly 4800 feet thick in section. It is estimated that more than 34,000,000 cubic yards of earthfill would be required in the construction of the dam.

Two systems of outlet works, each employing two intakes, would divert water from the reservoir for downstream releases. Two spillways of the glory hole type would be provided.

The reservoir impounded by the proposed English Ridge Dam would have a gross capacity of about 1,800,000 acre-feet at a water surface elevation of 1698 feet. The surface area of the water at that capacity would be approximately 11,800 acres. The reservoir, with its main arm extending to within a mile of Lake Pillsbury and another arm extending nearly 10 miles up Tomki Creek, would have a shoreline of 118 miles. The reservoir would be operated for flood control with a joint use conservation and flood control reservation of 50,000 acre-feet.

English Ridge Dam would form an impassable barrier to migrating fish and inundate spawning areas. To mitigate for the loss of natural spawning areas, a 50,000,000 egg-capacity fish hatchery would be built 3000 feet downstream of the dam. Reservoir operation would maintain adequate flows for fish preservation. Periodic flushing releases would prevent undue encroachment of plant growth and keep silted gravel from compacting. Normal fish releases would vary from 125 cubic feet per second to 220 cubic feet per second, averaging about 112,000 acre-feet per year.

English Ridge Reservoir would be a good potential recreation area. Existing roads approach the main recreation area from Willits, which is about 11 miles to the west. Overnight camping areas, picnic areas, boating facilities, running water, and sanitary facilities are included in the planned development. About 8000 acres of wooded and gently sloping land adjacent to the reservoir have been selected for recreation use.

English Ridge Reservoir area.

The Pacific Gas and Electric Company owns and operates a hydropower development system on the Upper Eel River, consisting of Lake Pillsbury, Van Arsdale Dam and Reservoir, and the Potter Valley Powerplant. The construction of English Ridge Dam and Reservoir would inundate Van Arsdale Reservoir, greatly increasing the head on the Potter Valley Powerplant. The existing powerplant would not be capable of utilizing this additional head without modification. The Bureau of Reclamation has prepared a feasibility design of a tunnel to replace a portion of the existing PG & E diversion tunnel.

An average of 212,000 acre-feet per year of project water would be conveyed from English Ridge Reservoir to Clear Lake by way of Garrett Tunnel or an alternative pipeline through Potter Valley. The tunnel would pass through Middle Mountain, its alignment roughly parallel to and approximately 3 miles easterly of a north-south axis of Potter Valley. The length of the 10- to 13-foot-diameter tunnel on this alignment would be 12.4 miles. It would discharge into Middle Creek about 9 miles upstream of Clear Lake. Water from the English Ridge Project could be used to meet water needs in the Clear Lake area, in the Putah and Cache Creek basins, and in Central Valley Project service areas.

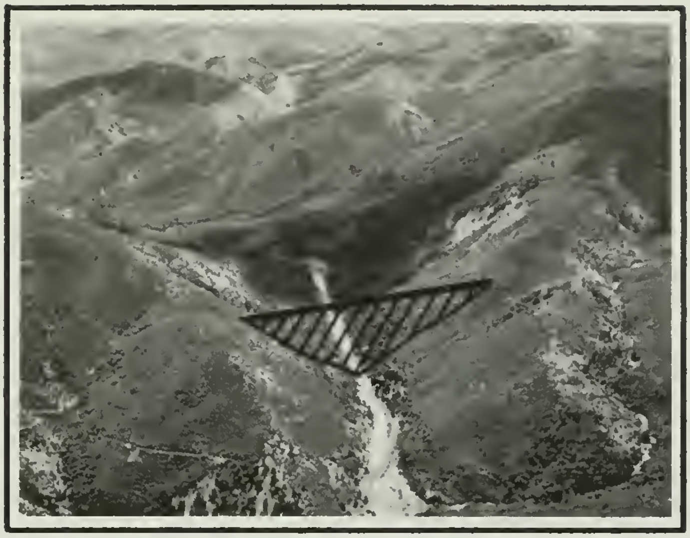
Cache Creek

Wilson Valley Reservoir

The three alternative reservoirs considered on Cache Creek and shown in Figures 1 and 3 are Wilson Valley, Kennedy Flats, and Blue Ridge. Wilson Valley is the smallest of these and has been long considered as a potential reservoir on Cache Creek. Kennedy Flats and Blue Ridge damsites were also investigated in an attempt to obtain more storage space on Cache Creek for the reregulation of Upper Eel River export flows. Wilson Valley Reservoir is described here.

Wilson Valley damsite is located on Cache Creek about 9 air miles northeast of the town of Lower Lake, which is situated near the outlet to Clear Lake. The reservoir size which was considered for route selection studies was 1,000,000 acre-feet, corresponding to a normal water surface elevation of 1228 feet and a surface area of 8600 acres.

Preliminary geologic investigations of Wilson Valley damsite indicate that the foundation is suitable for an earthfill dam of the height proposed, but they also identified a landslide area on the right abutment which limited the height of dam which it was felt could be safely constructed to the size previously mentioned. Further geologic exploration and evaluation of the hazard due to the landslide will be necessary before the site can be definitely declared safe for the size of dam proposed.



Wilson Valley damsite looking downstream/Note deep slide area on right abutment.

The dam section would rise above the streambed approximately 365 feet to an elevation of 1233 feet. The outlet works would consist of a 22-foot diameter valved tunnel discharging into a stilling basin. This tunnel would be used during construction for diversion of large flood flows and then would be used during operation for controlled releases of water to the Delta.

The spillway would consist of a side channel entrance section and a long open chute terminating in a flip bucket to disperse the water as spray.

Wilson Valley Reservoir would have a gross capacity of 1,000,000 acre-feet and a surface area of 8600 acres at the normal water surface elevation of 1228 feet.

CHAPTER 6. STUDIES OF ALTERNATIVE PROJECTS

This chapter discusses more fully those alternative plans for development on the Middle Fork Eel River and on the Clear Lake Route which were identified in Bulletin No. 136 and studied in the comparisons but were determined to be less feasible from an economic and engineering standpoint.

Middle Fork Eel River

The primary source of water supply for the Upper Eel River Development is the Middle Fork Eel River. A major consideration in formulation of any development on the Middle Fork Eel River is the effect on Round Valley. The following sections present discussions of the plans both with and without Round Valley and of the dams and reservoirs involved.

Alternative Projects to Protect Round Valley

During the route comparison studies, five alternative plans composed of three major damsites and three minor damsites were under consideration on the Middle Fork Eel River. The major damsites were Dos Rios, Etsel, and Spencer. The minor damsites, necessary to prevent inundation of Round Valley, were Mill Creek, Franciscan, and Wailaki.

The first of the five alternative plans is composed of a large Dos Rios Dam and Reservoir utilizing storage in Round Valley. Studies have shown this to be the best of the alternative plans for full development of the Middle Fork. This plan is described in detail in Chapter 5.

The second alternative considered was a large Dos Rios Dam and Reservoir with provisions for protecting Round Valley. Two of the smaller dams, Mill Creek and Franciscan, or Wailaki, an alternative to Franciscan, would be required to prevent stored water from backing into Round Valley. This scheme was envisioned as the largest possible development on the Middle Fork with protection of Round Valley. It was eliminated after study for the following reasons.

One of the smaller dams for protecting the valley with this plan would have been Mill Creek Dam, located on Mill Creek about one mile above its confluence with the Middle Fork. Although classified as a "minor" dam, it would have been over 300 feet high. The geology report on the damsite gave the opinion that it would be possible to construct a dam, but that the foundation rock, a weak slaty shale predominantly, is rather poor and conducive to considerable seepage. The Department recommended after review of the proposed plan that the Mill Creek site not be considered without considerable additional geologic exploration. In view of the serious difficulties with other elements of this plan, no additional exploration is planned.

Mill Creek damsite on Mill Creek, the natural drain to Round Valley in the background.

If a dam at Mill Creek were to be constructed it would be necessary to provide an outlet for the natural runoff into Round Valley. This would be accomplished by means of a 17-foot-diameter gravity-flow drainage tunnel from near the Mill Creek damsite to a point just downstream from the proposed Dos Rios Dam. The 4.8-mile long tunnel would be through rock described as moderately to very blocky and seamy and in places completely crushed.

This type of provision for drainage cannot be regarded with much favor, particularly because of the poor quality tunneling rock through which the tunnel would have to be driven. The admittedly remote possibility of tunnel failure would leave the valley with no outlet. The alternative of constructing a pumping plant was rejected because of the necessity for human operation and the possibility of a power outage during a severe storm. Furthermore, even with the tunnel in operation at full capacity, over 4000 acres in Round Valley would be flooded during a probable maximum flood. This would be nearly one-fourth of the valley area.

The second small dam needed to prevent inundation of Round Valley would be either Franciscan or Wailaki. Franciscan damsite is located on Short Creek in the northeastern corner of Round Valley. Wailaki damsite, an alternative to Franciscan, is located in a low saddle between the Middle Fork Eel River and Short Creek basins.

The foundation conditions at the Franciscan damsite are extremely poor. The damsite is situated in the central portion of a broad, northwest trending fault zone extending along Etsel Ridge and across Etsel Flat, and forming the northern boundary of Round Valley. This fault zone is generally referred to as the Etsel Ridge fault zone. Indications are that it is not a large single fault but rather a broad area several miles wide, consisting of multiple fault and shear zones. The rocks in this zone are badly fractured and often are reduced to clay gouge.

In October 1966, the Department declared Franciscan damsite entirely unsuitable for the height of dam being considered. The decision was based on field examinations of the site, study of drill cores, and geologic mapping. Much of the exploration was done by the Corps of Engineers, who provided the Department with their records.

Wailaki damsite was investigated as an alternative to Franciscan damsite after it was declared unsuitable. Located on the fringe of the Etsel Ridge fault zone, Wailaki was the only possible alternative and this damsite is also of questionable geologic quality. Surface exploration at the damsite determined that rock exposures are scarce, indicating a corresponding lack of suitable underlying rock for foundations. The rocks adjacent to the fault zone boundaries have undergone severe faulting locally which may be related to the major fault zone. From geologic experience on the Middle Fork, subsurface exploration generally uncovers problems which are not discernable on the surface. In all probability, a drilling program at Wailaki would disclose problems similar to those at Franciscan. For this reason, no further exploration was conducted.

In addition to the unfavorable geologic qualities discussed above, the plan consisting of a large Dos Rios Reservoir with protection for Round Valley would be very expensive. Its cost and operating capabilities, as compared to a large Dos Rios inundating Round Valley, are shown in Table 10. The third plan shown for comparison consists of the small Dos Rios Reservoir at a normal water surface elevation of 1320 feet, which does not encroach on the valley, combined with large storage in the Glenn Complex. This plan is discussed later in this chapter. In addition to the actual costs of Dos Rios Reservoir, the incremental cost of the longer Dos Rios--Grindstone Tunnel required for a protective scheme must be added, as well as the cost of enough active storage in the Glenn Complex to bring the total yields of the three plans up to parity. On this basis of comparison, either $107,000,000 or $188,000,000 would have to be expended to protect this valley. The present estimated market value of the valley is $25,000,000.

The alternative plan of protecting Round Valley while building a large Dos Rios Reservoir so as to fully develop the Middle Fork Eel River was eliminated because of geologic and operational unsoundness of the necessary features and because of the very high cost. The remaining alternative of constructing a lower Dos Rios Dam is still under consideration. The 536,000 acre-feet of storage would not begin to control the Middle Fork Eel River, but until the scale of development is determined, this project alternative will not be eliminated. It remains a possibility if it is decided for financial reasons to proceed with less than full development of the Middle Fork Eel River.

Etsel and Spencer Dams and Reservoirs

Another Middle Fork Eel River project alternative considered was a small Dos Rios Reservoir in combination with either Spencer or Etsel Reservoir. Dos Rios Reservoir would serve as a diversion facility while Spencer or Etsel Reservoir would be located upstream and would provide storage to control and reregulate the Middle Fork flows.

Under this plan Dos Rios Reservoir would be limited to a storage of 536,000 acre-feet at an elevation of 1320 feet. At this elevation the reservoir would not back into Round Valley.

TABLE 10

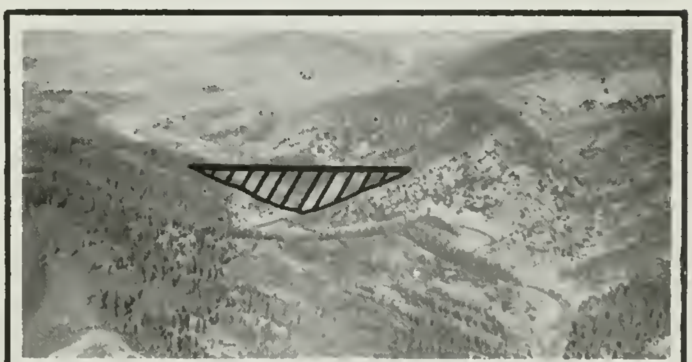
COMPARISON OF ALTERNATIVES FOR DEVELOPMENT OF THE MIDDLE FORK EEL RIVER

	Dos Rios With Round Valley	Dos Rios Without Round Valley	Dos Rios Without Round Valley
Main Dam Height (feet)	705	705	415
Reservoir Storage (acre-feet)			
a. Gross	8,000,000	3,600,000	536,000
b. Active	6,500,000	2,900,000	
Average Annual Diversion to Sacramento Valley (Acre-feet per year)			
a. Long period	815,000	833,000	690,000
b. 7-year dry period	1,160,000	670,000	357,000
Project Export Yield to Delta (Acre-feet per year)			
a. Long period	815,000	875,000	880,000
b. 7-year dry period	1,160,000	1,160,000	1,130,000
Capital Cost of Dos Rios Dam and Reservoir	$198,400,000	$228,100,000	$ 42,600,000
Incremental Tunnel Cost 1/		14,000,000	14,000,000
Cost of Additional Storage Features to Make Dry Year Yields Comparable			
Paskenta Reservoir - 105,000 acre-feet			$ 10,000,000
Newville Reservoir - 2,920,000 acre-feet			96,500,000
Rancheria Reservoir - 4,080,000 acre-feet			142,500,000
Rancheria Reservoir - 4,150,000 acre-feet		$144,700,000	
Subtotal		$144,700,000	$249,000,000
Total Capital Cost	$198,400,000	$386,800,000	$305,600,000

1/ 23.4 miles long versus 21.2 miles for first alternative.

Both Spencer and Etsel Reservoirs would require Franciscan or Wailaki Dams as a protection for Round Valley. As mentioned above, Franciscan damsite has been eliminated and the geologic soundness of the Wailaki damsite appears to be questionable in view of the exploration undertaken and experience with the nearby Franciscan damsite.

Spencer and Etsel damsites are located near Etsel Flat on the Middle Fork Eel River upstream from its confluence with Mill Creek. Spencer damsite is situated in the central portion of the Etsel Ridge fault zone. This has been confirmed by foundation exploration which has revealed large areas of broken



Etsel damsite looking upstream on the Middle Fork Eel River.

rock and fault gouge. Etsel damsite is located immediately to the southwest of the fault zone. Extensive drilling at the site by the Corps of Engineers and the Department has revealed that the foundation rock contains numerous small faults which have probably contributed to the development of an extensive landslide found on the left abutment. Removal of this landslide would be necessary. This would not solve the problem, however, as a new landslide could be expected to develop above the removed area. For these reasons the Department recommends that Etsel damsite no longer be considered until further exploration eliminates geologic uncertainties at the site. After extensive explorations, the Corps of Engineers has also abandoned the site as of questionable engineering soundness and economic feasibility.

Although comparable in yield to one of the smaller sizes of Dos Rios Reservoir inundating Round Valley, the Dos Rios--Spencer and Dos Rios--Etsel combinations do not compare favorably in cost of construction. This is illustrated below in Table 11. Because of the higher costs and geologic uncertainties associated with these latter projects, they were eliminated from further consideration.

The fourth alternative studied was in connection with the Glenn Route only. It consisted of a single reservoir diverting water to the proposed Paskenta-Newville Project. The physical features would include a Spencer or Etsel Dam and either Franciscan or Wailaki Dam to protect Round Valley. Envisioned as a low cost -- low yield project, it was eventually rejected due to the poor geology previously discussed, and to the higher costs estimated for Spencer and Etsel Dams.

Spencer damsite looking upstream on the Middle Fork Eel River.

Clear Lake Route

Stienhart-Jerusalem Power Development

The Stienhart-Jerusalem Hydroelectric Power Development is dependent upon the diversion of water from Clear Lake into Putah Creek

TABLE 11

COMPARISON OF ALTERNATIVES FOR DEVELOPMENT OF THE MIDDLE FORK EEL RIVER

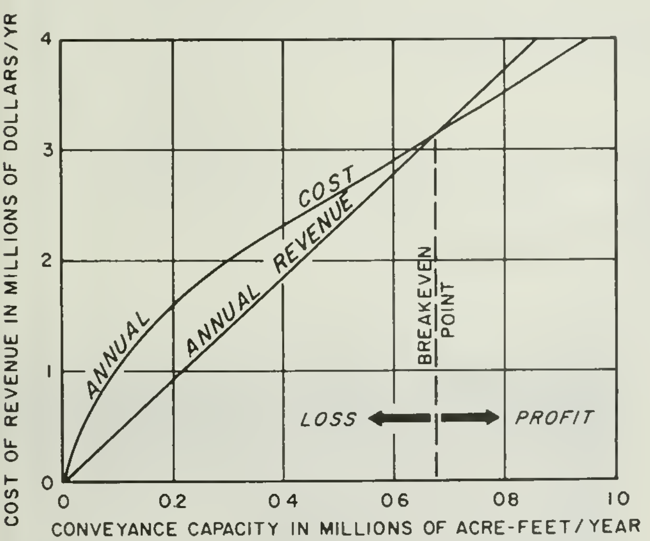
	Dos Rios Inundating Round Valley	Spencer--Wailki and Dos Rios Combination	Etsel--Wailaki and Dos Rios Combination
Reservoir Storage (Acre-feet)			
a. Gross	2,800,000	1,510,000	1,510,000
b. Active	1,300,000	1,310,000	1,310,000
Average Annual Diversion to Sacramento Valley (Acre-feet per year)			
a. Long Period	840,000	840,000	840,000
b. 7-Year Dry Period	450,000	450,000	450,000
Project Capital Cost	$129,800,000	$149,600,000	$156,700,000

and Lake Berryessa. The power development would consist of Stienhart Dam, Reservoir, and Powerplant, located on Soda Creek, with a normal water surface elevation of 1300 feet, and Jerusalem Dam, Reservoir, and Powerplant on Soda Creek below Stienhart Reservoir, with a normal water surface elevation of 1045 feet.

The projects would be constructed solely for power generation; no significant recreation enhancement would occur. Thus their justification rests entirely on the feasibility of power generation at the sites.

Figure 18 shows the relationship between estimated costs and expected revenues for the power development.

The figure shows that for firm annual diversions of less than 675,000 acre-feet the power installations would not be economically justified. As this is near the upper limit of the amount of firm annual diversion from the Middle Fork Eel River, it was concluded that power generation at Stienhart and Jerusalem would have no bearing on the route comparisons, and this plan was dropped from further consideration.



SODA CREEK POWER FACILITIES
ESTIMATED COSTS AND REVENUES
FIGURE 18

Enlarged Lake Berryessa

The possibility of use of either the existing Lake Berryessa or an enlarged lake was considered in the studies culminating in Bulletin No. 136 in 1964. The reservoir was therefore initially considered in the route comparisons. As more became known, however, concerning the problems associated with this alternative, it was gradually relegated to a position behind the more favorable alternatives on Cache Creek. The purpose of this section is to describe in summary form the reasons for rejection of the alternative route via Putah Creek and Lake Berryessa.

One of the main reasons for consideration of enlarged Lake Berryessa in the Bulletin No. 136 studies was development of hydroelectric power through development of a pumpback scheme from the Sacramento River.

An enlarged Lake Berryessa was considered in the route comparison studies from the standpoints of the pumpback power scheme and providing for storage and reregulation of the flows from the Upper Eel River. The pumpback scheme was rejected because of its large capital investment, the uncertainties regarding availability of surplus water in the Sacramento River and the lack of an established market for the large block of hydroelectric power which would be generated. However, the dynamic market for hydroelectric power may justify reconsideration of the power potential in the distant future.

Two sizes of an enlarged Lake Berryessa were considered from the standpoint of reregulatory storage in the analyses leading to this report. They were a 5,000,000 acre-foot capacity reservoir with a normal water surface elevation of 570 feet and an 8,000,000 acre-foot capacity reservoir with a normal water surface elevation of 650 feet. It would be physically possible to impound about 16,000,000 acre-feet in an enlarged lake, but the 8,000,000 acre-foot size would be the largest usable with the available export flows from the Middle Fork Eel River.

To enlarge the lake, the existing Monticello Dam would be replaced by a rockfill structure about one mile downstream. The higher lake level would mean that essentially all of the existing developments around the lake would have to be relocated. The Lake Berryessa recreation area is one of the fastest growing areas in Northern California and to relocate all facilities and residences on the lake would mean tremendous economic and sociologic problems. The cost of acquisition and relocation alone for an enlarged reservoir has been estimated at over $60,000,000 at the present time.

In addition to the cost of relocation, a reservoir of 8,000,000 acre-feet would require about 13 years to fill in addition to the time needed to fill upstream reservoirs. During that time all of the new facilities would be as much as several thousand feet from the slowly advancing shoreline. Drawdown of storage during a dry period would start the long filling process over again.

The importation of warm Clear Lake water, with its high level of nutrients, into Lake Berryessa could cause a problem in the upper portion of the enlarged lake due to algae blooms. The warmer water could affect the existing stratification of water temperatures in the reservoir, possibly making the lake unsuitable for production of trout. If releases from the reservoir were not properly controlled, damage or loss to the existing trout fishery on Putah Creek could also occur.

For the foregoing reasons, in addition to cost of the dam and reservoir, filling problems, high cost of conveyance to the Sacramento River and high annual evaporation losses, the Lake Berryessa alternative was rejected in favor of the Cache Creek alternative for routing of water from the Upper Eel River.

Putah Creek Conveyance System

The Putah Creek Conveyance System would consist of the necessary canals, siphons, and pipelines to transport export water from an enlarged Lake Berryessa to the Sacramento River. Two alternative alignments were considered. One was down Putah Creek; the other was a diversion to the alternative Cache Creek Conveyance System. The alternative alignments are shown on Figure 3.

As shown in Table 12, the Putah Creek alignment is less expensive than the route from Lake Berryessa to Cache Creek and then down the Cache Creek Conveyance System. The diversion of large volumes of water through the Putah Creek Route, however, would probably destroy the present trout fishing in Putah Creek. The problems of mitigating for this destruction, combined with those related to construction of the conveyance system across the Yolo Bypass and the deep water ship canal, favored the choice of the Cache Creek Route. When it was shown that economically it would be better to route the water down Cache Creek instead of through Lake Berryessa, both Putah Creek alternatives were eliminated.

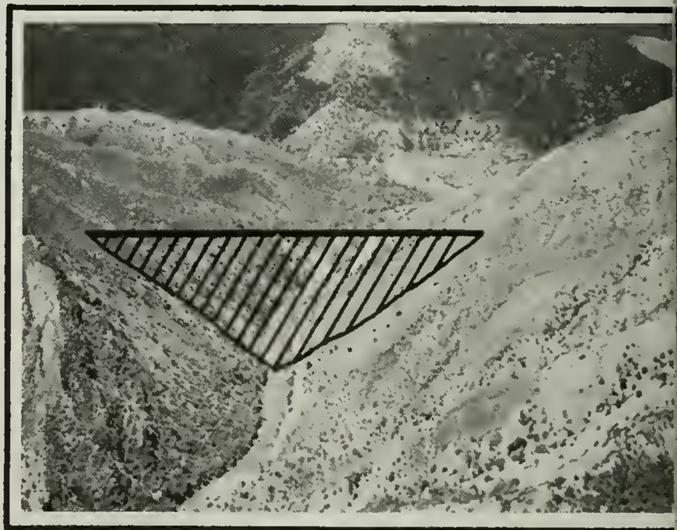
TABLE 12

COMPARISON OF CONVEYANCE SYSTEM COSTS
CLEAR LAKE ROUTE

	Berryessa-Putah Creek	Berryessa-Cache Creek	Blue Ridge-Cache Creek
Total Capital Cost	$10,800,000	$21,700,000	$4,100,000

Blue Ridge Dam and Reservoir

On Cache Creek, three alternative damsites were given consideration: Wilson Valley, Kennedy Flats, and Blue Ridge. The Wilson Valley site has long been considered by the Department as a favorable damsite. However, exploration conducted in the late 1950's during the Bulletin No. 90, "Clear Lake--Cache Creek Basin Investigation", indicates that a large landslide on one abutment would limit the size of dam which could be constructed. The maximum size of dam considered would impound a reservoir of 1,000,000 acre-feet. When operation studies indicated that more storage on Cache Creek would be necessary, Kennedy Flats and Blue Ridge damsites were considered. The Kennedy Flats damsite is approximately 3 miles downstream of the Wilson Valley site. It would have a potential storage capacity of 2,250,000 acre-feet. Blue Ridge damsite is approximately 12 miles downstream of the Wilson Valley site,



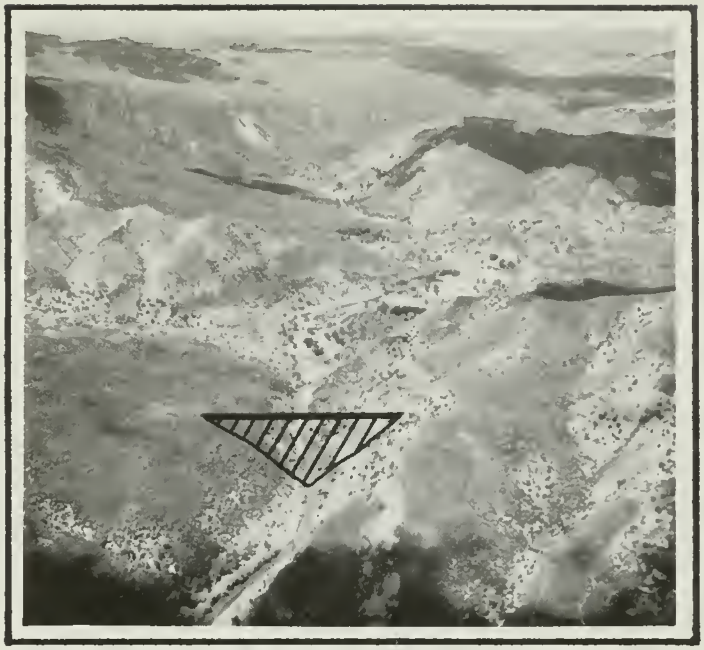
Blue Ridge damsite on Cache Creek. View looking upstream.

about a mile above the upper end of the Capay Valley. Its potential storage capacity would be approximately 4,000,000 acre-feet. Reconnaissance-level geologic exploration was performed at these sites and designs and cost estimates prepared.

There is no distinct disadvantage, geologically speaking, to any one of the three alternative sites. The economic analyses showed, however, that it would be economically more favorable to concentrate the large amount of long-term carryover storage on the Clear Lake route in Dos Rios Reservoir rather than on Cache Creek. This economic advantage is illustrated in Table 13.

The use of the Blue Ridge damsite would require a dam 775 feet high to impound 4,000,000 acre-feet of storage. Extensive further exploration would be required to determine definitely if the Blue Ridge and Kennedy Flats sites are feasible for construction of large dams. In addition, these large reservoirs would inundate extensive wildlife habitat.

For these main reasons the Cache Creek alternative of Blue Ridge Dam and Reservoir was eliminated in favor of smaller, less costly reservoirs at the Wilson Valley or Kennedy Flats sites.



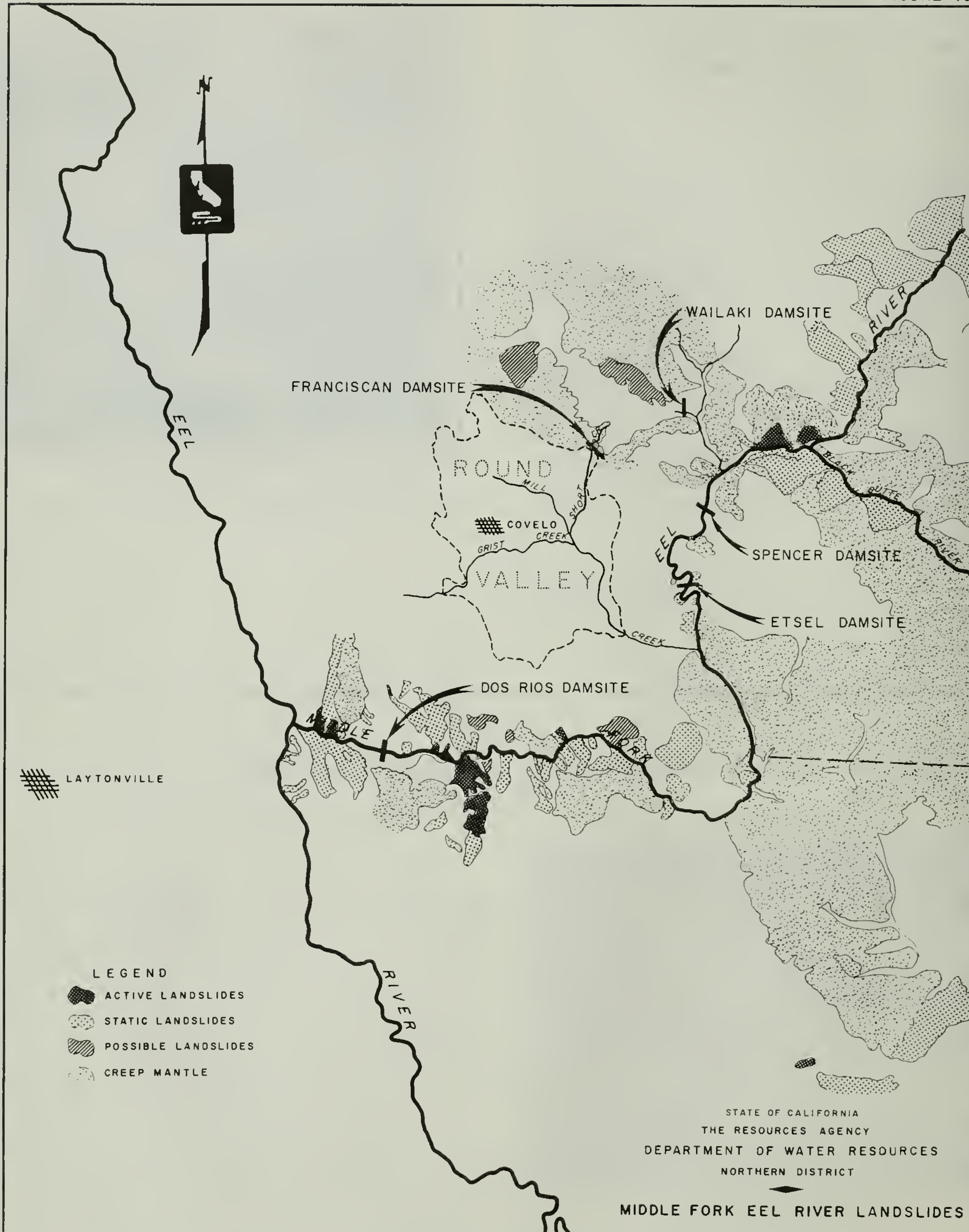
Kennedy Flats damsite on Cache Creek. View looking upstream.

TABLE 13

COMPARISON OF ALTERNATIVE PROJECTS ON CACHE CREEK

	Dos Rios-Wilson Valley	Dos Rios-Blue Ridge
Reservoir Storage (Acre-feet)		
a. Dos Rios	6,000,000	3,000,000
b. Cache Creek	1,000,000	4,000,000
Project Export Yield (Acre-feet per year)		
a. 7-Year Dry Period	943,000	974,000
b. Long Period	603,000	682,000
Project Capital Cost	$606,650,000	$721,500,000
Project Benefit-to-Cost Ratio	1.37	1.17
Project Net Benefits	$222,900,000	$126,500,000
Unit Cost of Delta Yield (Dollars per Acre-foot)	$20.10	$24.85

FIGURE 19



WAILAKI DAMSITE
FRANCISCAN DAMSITE
ROUND
VALLEY
COVELO
MILL
SHORT
GRIST
CREEK
SPENCER DAMSITE
ETSEL DAMSITE
DOS RIOS DAMSITE
EEL
RIVER
BLACK
BUTTE
LAYTONVILLE
LEGEND
ACTIVE LANDSLIDES
STATIC LANDSLIDES
POSSIBLE LANDSLIDES
CREEP MANTLE
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
MIDDLE FORK EEL RIVER LANDSLIDES

CHAPTER 7. SPECIAL STUDIES

The studies discussed in this chapter involve considerations which have a bearing on the future planning studies for the Upper Eel River Development. These considerations will influence the timing of construction and the sizes of reservoirs finally chosen.

Construction of Upper Eel Projects for Flood Control

Senate Concurrent Resolution No. 14, adopted at the 1965 Session of the Legislature, requested the Department of Water Resources to give high priority to the planning and construction of dams on the Upper Eel River for flood control purposes.

In a letter report transmitted to the Legislature in December 1966, the Department presented information on the Eel River flood problem, the status of Eel River planning, and a discussion of possible advantages, in addition to flood control, that could result from early construction of the Upper Eel River Development. The following are excerpts from that letter report.

"The flood of December 1964 was the largest, most destructive flood in the recorded history of the North Coastal area. The Eel River Basin was the hardest hit; 19 lives were lost and $82,000,000 in damage resulted.

"An effective flood control system in the Eel River Basin to prevent reoccurring major damage is going to require the construction of levees, and dams and reservoirs, augmented with floodplain management.

"The best early solution for flood control in the Eel River Delta would be construction of the authorized levee project scheduled by the Corps of Engineers to start in 1969.

"The major portion of the cost of Eel River dams and reservoirs would be allocated to water supply and be borne by the water user. As such, it would be financially advantageous to defer construction of these projects until they are needed for water supply; earlier construction for flood control purposes would require another source of financing.

"One possible way of achieving early development would be through federal construction with state participation under the Water Supply Act of 1958. Under this Act, repayment of [a portion of] the water supply allocation could be delayed for up to ten years, or until first use of the water, with no interest charged.

"It may be advantageous to construct the Upper Eel River Development sooner than it would be needed for water supply, not only from the viewpoint of providing urgently needed flood control in the Eel River Basin, but also from the statewide viewpoint as regards possible improvement of water quality in the Sacramento--San Joaquin Delta, hydroelectric power, and as a possible source of exchange water for the Colorado River Basin.

"One of the possible purposes of the Upper Eel River Development could be water quality improvement in the Sacramento--San Joaquin Delta. If this proves feasible, a portion of the project cost could be assigned to this purpose, thereby enhancing the possibilities for early construction.

"Although the possibilities for on-site power generation with the Upper Eel River Development are limited, there does appear to be a possibility, by coordinated operation, for increasing the power production at existing plants such as Oroville, Shasta, and Folsom. The revenue from this expected increase in system power production could assist in financing the Upper Eel River Development.

"The Eel River could possibly serve as an early but interim supply for the Pacific Southwest, pending development of an interbasin transfer system that would provide long-term augmentation of the water supply of the Colorado River.

"The Department will continue in its intensive planning effort with the federal agencies to formulate a plan leading toward construction of multiple-purpose reservoirs on the Eel River. When selection is made of the conveyance route in mid-1967 for delivering water from the Middle Fork Eel River, the Department will be in a position to concentrate on definite plans for construction of the Middle Fork Eel River dams and reservoirs. The Upper Eel River reservoirs in combination with the Eel River Delta levees will provide the first stage of urgently needed flood control."

Although the possibilities for early construction of Dos Rios and English Ridge Reservoirs for flood control are not promising, the Department will continue to explore them, especially with regard to the use of the Water Supply Act of 1958 for financing of Dos Rios Dam and Reservoir.

Paskenta-Newville Project

The Legislature at the 1966 First Extraordinary Session adopted three resolutions requesting that the Department initiate with the Federal Government an action program for early construction, on a joint venture basis, of the Paskenta-Newville Project.

A department report, prepared in response to these resolutions, was transmitted to the Legislature in December 1966. It contained a description of the Paskenta-Newville Project, discussion of the need for the project, a summary of state-federal coordination on the project, and a discussion of key factors to be considered in future state-federal negotiations leading to construction of the project. The following excerpts are from that report.

"The Paskenta-Newville Project is one of the more favorable remaining water projects in the Sacramento Valley. It would provide flood control, recreation, and a block of conservation yield to meet local and statewide needs. The most urgent need is for effective flood control on Thomes Creek.

"The members of the California-Federal Interagency Group have achieved a significant degree of cooperation on the planning of the Paskenta-Newville Project during the last two years through the joint development of planning principles and the exchange of topographic, geologic, and hydrologic data. The general interests of each member agency have been defined and recognized by the others, thus providing a basis for orderly, economical development to proceed.

"The most significant step in planning coordination was taken on September 1, 1966, with the signing of an interagency agreement regarding feasibility-level planning on the Paskenta-Newville Project and other projects in the Sacramento River Basin. The agreement assigns primary responsibility to the Bureau of Reclamation for completion of feasibility-level planning and the seeking of federal authorization for the Paskenta-Newville Project, which is to be planned as a joint use state-federal project.

"On September 28, 1966, Congressman Leggett introduced HR 799 calling for authorization of the Paskenta-Newville Project as a unit of the federal Central Valley Project. The bill included provision for joint project construction, operation, and use with the State of California."

The report concluded that:

1. The Paskenta-Newville Project has been authorized by the State as part of the Upper Eel River Development. However, in the light of the recent interagency agreement, the Bureau of Reclamation would construct the Paskenta-Newville Project as a joint use facility to be integrated into the State Water Project and the federal Central Valley Project. The time of construction would be determined by negotiations, considering probable filling time, statewide project scheduling, economic justification, and the interim and ultimate use of the project.

2. Preferably, the Federal Government should finance the Project, with the State participating under the provisions of Title III of the Water Supply Act of 1958, or some similar arrangement providing deferred payment of allocations to future water supplies. If authorization and construction cannot be accomplished in a time and manner acceptable to the State, the State should proceed with construction.

The report recommended that:

1. The State of California support federal authorization of the Paskenta-Newville Project. In the event that federal authorization cannot be obtained the State should construct the project.

Landslides on Middle Fork Eel River

As part of the activities for Phase II of the Advance Planning Program, a Landslides Investigation Program was initiated in the summer of 1966. This program has as its objective determination of the location, extent and volume of all landslides in the reservoir area. The amount of material which would enter the reservoir during the project's life and the effects of large rapid movement slides, should they occur, will also be estimated. This information will be used in the design of the dam and other features around the reservoir.

The predominant rock types in the reservoir area on the Middle Fork Eel River are the shales, sandstones, and serpentines of the Franciscan Formation of rocks. Locally, in an area upstream from Dos Rios damsite, there exists a broad band of Cretaceous and Miocene shales and sandstones. These materials, as well as the highly sheared Franciscan rocks, are deeply weathered. This weathering has produced a thick mantle of soil and very weak rock overlying the slopes in the reservoir. Removal of the toe of this soil mantle by the active down-cutting action of the Eel River, in addition to the reduction of shear strength and extra loading caused by the abundant rainfall seeping into the soils, has produced widespread slope instability. This has shown itself in creep of the soil mantle and in deep landslides. The location of recognized landslides in the reservoir area is shown on Figure 20.

This slow, relentless accumulation of soil creep and landslide material will eventually reduce the active storage capacity of the reservoir. Large, rapid landslides could block or impede the movement of water through the reservoir, could cause destructive waves and could alter the scenic value of the reservoir by leaving unsightly scars on the otherwise verdant slopes.

The landslides investigation program provides for field work to locate slides and to monitor their activities through the use of aerial and ground surveys, subsurface instrumentation and photography. The results of this field work will be used to provide data for modeling landslide occurrence in a scale model of the proposed reservoir to determine the height and type of possible destructive waves, should a large slide suddenly slip into the reservoir. The results of the field work and the modeling activities will be presented in a report on landslide hazards for inclusion as an appendix to the Advance Planning Report.

Although the greater portion of the landslide program is expected to terminate in 1970, monitoring will continue to provide more information as necessary. The program represents a pioneering effort in the field of landslide study, both in scope and in size.

Watershed Management

The various study aspects necessary to outline an effective program of watershed management on the Eel River are being studied by the U. S. Soil Conservation Service at the request of the Department. The Eel River is a prolific sediment producer; during the December 1964 flood, over 100,000,000 tons of sediment washed from the basin.

The objectives of the study being conducted by the Soil Conservation Service are:

1. To identify areas of origin of sediment and causes of sediment production.

2. To determine appropriate conservation measures to reduce sediment production and protect water quality.

3. To identify projects and overall programs best suited to conserving the soil and maintaining clear water for beneficial uses.

The report on watershed management will describe the efforts of the U. S. Forest Service, the U. S. Economic Research Service and the State Departments of Conservation and Water Resources. Each agency is providing data in cooperation with the Soil Conservation Service, which is providing the framework of the study.

Extensive field work is presently being done to locate sources of sediment and to analyze these sources. The analysis will provide an estimate of expected future sediment production and the proportion of sediment produced by the various sources. Sources of sediment can be landslides, fires, roads, logged and grazed-over lands, gullies and streambeds. The program will propose remedial actions to lower sediment production.

These remedial programs proposed in the report could take the form of construction of small conservation dams under Public Law 566, restrictions on land use in specific areas of high sediment production, or limitations regarding types and placement of roads in the basin.

The results obtained from this watershed management study will be of great value in establishing the necessary reservoir storage reservation for sediment storage, and in the location and design of intake and outlet structures. The report will be published by the Soil Conservation Service in 1968.

CHAPTER 8. CONTINUING AND RELATED STUDIES

The publication of this report completes the route selection phase of the Department's Advance Planning Program on the Upper Eel River Development. This chapter describes the future planning studies which will provide the basis for final design of the project. In addition to the Advance Planning Program, the Department will be involved in three other planning studies which could be influenced by or could influence the Upper Eel River Development. These studies, which are discussed in this chapter, are: the North Coastal Area Investigation, the North Coastal Action Program, and the Upper Sacramento River Basin Investigation. All of these studies are being conducted in close cooperation with federal, local, and other state agencies.

Advance Planning on Selected Route

The Advance Planning Program on the Upper Eel River Development will be continued to provide final formulation of the project. As described in Chapter 1, this project, as tentatively formulated, would consist of Dos Rios Dam and Reservoir on the Middle Fork Eel River, Dos Rios--Grindstone Tunnel, elements of the Glenn Reservoir Complex, and conveyance facilities to the Sacramento River.

The objectives of this program are: (1) to identify the specific project features which will comprise the Upper Eel River Development; (2) to define the nominal capacities, sizes, and other parameters of the selected features; (3) to identify local needs which could be served from the development and define the appurtenant works necessary to supply these needs; (4) to determine the relationship between projected benefits and estimated costs for the project as a whole and for the individual project purposes, in order to provide a cost allocation and a project services allocation among the various purposes; and (5) to provide comprehensive recommendations for the subsequent programs and actions which will be necessary to design, construct, and operate this facility.

Middle Fork Eel River

The Department shares with the Corps of Engineers the responsibility for formulation of the project on the Middle Fork Eel River, tentatively identified as Dos Rios Dam and Reservoir and appurtenant facilities. This coordinate responsibility will include project sizing, financial studies to demonstrate feasibility, and preparation of a final planning report. In addition to the joint formulation responsibility, the Department has primary responsibility for overall coordination and for the fish and wildlife, recreation, and water rights aspects of Middle Fork Eel River planning.

Further studies will be required to define a program for acquisition of lands within Dos Rios Reservoir, to make a final selection of the required size of the reservoir, and to size project features such as outlets, the fish hatchery, recreation facilities, and the dam itself.

Dos Rios--Grindstone Tunnel

The Department has the primary responsibility for all aspects of planning for this conveyance facility. Continuing planning will require further exploration of the tunnel, including several deep holes, to more completely define the expected conditions at tunnel grade.

Further planning will also take into account the possibility of increasing the tunnel size beyond that necessary for diversion of Middle Fork Eel River flows, to allow for future routing of water from lower main Eel River dams through Dos Rios Reservoir.

Glenn Complex

The primary responsibility for all planning aspects of Rancheria Dam and Reservoir and the conveyance works to the Sacramento River rests with the Department. The Bureau of Reclamation has primary responsibility for planning on Paskenta-Newville under the terms of the interagency agreement.

An objective of the Advance Planning Program will be to determine whether Newville Reservoir should be used for storage of Middle Fork Eel River diversions in conjunction with Rancheria Reservoir or whether use of Rancheria alone would be preferable.

Other aspects which will require additional study are the possibilities of establishing a salmon run in Thomes or Stony

Creek, of using flat marshy areas near the reservoirs for the development of wildfowl areas, and of enhancing recreation possibilities of East Park and Black Butte Reservoirs.

Coordination With System

Further studies will be necessary to define the manner in which the Upper Eel River Development will fit into the State Water Project and Central Valley Project system. An important aspect of these studies will be identification of a market for the supplemental water that can be provided by the Upper Eel River Development.

Studies to determine the effect upon seepage problems of releases from the project into the Sacramento River, when coordinated with the system, will also be required. In conjunction with the results of the Sacramento River Seepage Investigation, these studies will determine if seepage problems will be aggravated by the introduction of Middle Fork Eel River water.

North Coastal Area Investigation

The second phase of the Department's continuing planning investigation of the entire North Coastal area is currently underway. The first phase was reported on in Bulletin No. 136 in 1964. The various studies under this investigation are funded from the State General Fund. They are described in the following sections.

South Fork Eel River Basin Study

The purpose of this study was to make a selection of small reservoir projects for further detailed study. Water supply, recreation, flood control, and fisheries enhancement were the project purposes considered. The results are presented in Bulletin No. 173.

Lower Trinity and Klamath Rivers Study

This is a reconnaissance study to define major multiple-purpose projects on the lower Trinity and Klamath Rivers. It will also compare the relative merits of several alternative conveyance routes to the Sacramento Valley. One of these alternatives is the Westside Conveyance System, which would deliver water to the Glenn Complex for reregulation. The results of this study and those of the Upper Eel Advance Planning Program will be mutually dependent.

Eel River Basin Master Plan

This study is a result of the interagency decision to proceed with planning for the Eel River Basin on the basis of a basin master plan. It will be a study to integrate all Eel River planning into one comprehensive master plan. The Department has the major responsibility for coordination of planning efforts and for report preparation.

North Coastal Action Program

The purpose of the North Coastal Action Program is to define possible local projects within the North Coastal area and to formulate action programs which will lead to construction of priority projects. The emphasis in this investigation will be on the Smith, Mad, Van Duzen, and South Fork Eel River Basins. This study will be complementary to the ones previously described. The study was reported upon in Bulletin No. 105, "Developing the North Coast, An Action Program", published in December 1966.

Upper Sacramento River Basin Investigation

This program is a reevaluation of those projects presented in the Department's Bulletin No. 150, giving a special emphasis to flood control. A preliminary master plan for flood control in the Upper Sacramento River Basin will be prepared in cooperation of the Corps of Engineers as part of this investigation.

INDEX